LEFFEL'S

CONSTRUCTION OF MILL DAMS,

—AND—

BOOKWALTER'S

MILLWRIGHT AND MECHANIC.

ILLUSTRATED BY NUMEROUS FULL-PAGE PLATES.

SPRINGFIELD, OHIO:
JAMES LEFFEL & CO.,
PUBLISHERS.
1881.

PREFACE.

No work relating to a special branch of industry has met with a more cordial reception than the large octavo volume entitled "The Construction of Mill Dams," issued by the publishers of the present work in 1874. The size of the former book was due in part to the heavy paper, liberal margins and large type employed; and while these features added greatly to its exterior appearance without affecting its practical value, the price was also necessarily much enhanced. Nevertheless, a large edition of the work, even in this comparatively costly form, was exhausted by the wide and constant demand for a treatise of that kind. This demand had never before been met; no complete work on the subject, and especially none of a strictly practical and useful character, having up to that time been offered to the public. The remarkable popularity of the book, it is believed, was owing not only to the fullness and accuracy of the descriptions given, but also to the fact that technical and abstract terms were as far as possible excluded, and the work rendered practically available to every owner or utilizer of water power.

To meet the steadily continued call for the book, the publishers now present a revised edition, at a price which brings it within the reach of all classes, and in a form highly convenient for the purposes of a handbook. They have also consolidated with it another valuable work entitled "Bookwalter's Millwright and Mechanic," in which are contained a large number of Tables and Rules pertaining to Practical Hydraulics, Milling, the Mechanical Trades and General Business, and a variety of Facts, Figures, Methods, Directions and Suggestions, which mechanics of every class, and especially owners or operators of mills, of whatever description, will find of constant use and value.

JAMES LEFFEL & CO.

SPRINGFIELD, OHIO.

PART I.

THE CONSTRUCTION OF MILL DAMS.

CHAPTER I.

MATERIAL AND FORM OF DAMS.

The weirs or dams thrown across the beds of rivers have been constructed in a great variety of shapes and of different materials, some of them too costly for general use in a country where small mills are chiefly needed. In cases where the supply of water is large and a high fall is not demanded, a temporary dam composed of boulder stones is sometimes thrown across the stream in a diagonal or slanting direction, and of length considerably greater than its breadth. The water is thus partly forced into the conduit or race above the dam, and the remainder passes over the surface of the dam in a shallow sheet. Being hastily and cheaply built, a dam of this kind may be repaired without much outlay, but the inconvenience of doing this after every heavy rise of the stream is a material drawback on its value.

In contrast with this comparatively rude species of dam are those of more solid structure, substantially built of stone, and stretched across the river in the form of a bow, the curve being against the current—the middle of the dam, in other words, being higher up the stream than the two ends. A dam of this sort, if provided with massive stone abutments, presents a firm resistance to the onset of a flood, and will stand any test ordinarily experienced. It may be made with a gentle slope from the crest both up and down the stream; or with a steep descent on each side, making its walls almost perpendicular ; or again with either a steep or sloping front on the upper side and on the lower a curved apron, the wall rounding downward from the top like the lower half of the letter C, by which arrangement the fall is made gradual and its force abated.

In a stream of moderate size, a form of weir has sometimes been adopted resembling the letter V, with the apex or point directed up stream. If built upon piles, with a frame of timber forming an inclined plane upon the face of the dam, and filled up with gravel surmounted by a mass of boulder stones well packed in, the dam will

be nearly impenetrable by water. The position of the two arms of the V distributes the force of the water in passing over, and as the currents descending from either side tend toward the centre of the stream, the banks are less liable to be washed away. If timber is abundant, the frame, instead of having a uniform slope downward on the face of the dam, may be made in a series of steps like a wide stairway, breaking the water into cascades. The piles for such a dam may be placed at right angles with the current, stayed and covered with plank, and made watertight with sheet piling supported by foot piles. Constructed in other respects like the one last described, a dam of this kind will possess great durability and admit of no leakage.

An undue accumulation of water above the dam may be remedied by a channel and sluice gate in one of the side walls, by which the surplus water may be drawn off before reaching the crest of the dam. A self-adjusting dam of heavy planks strongly framed together is sometimes stretched across the stream, connected by hinges to the crest of the permanent dam, and held in an upright position by weights passing over wheels on the abutments. In case of a flood the weights give way partially to the increased pressure and the auxiliary dam is let down toward a horizontal position, allowing the water to pass unobstructed. In place of an appendage of this kind, movable flash boards are often used, being held in place by pins and other supports along the brink of the dam, and tightly fitted to each other. In time of low water, the flash boards are of important service in obtaining sufficient head. When the stream rises, the boards are removed (though the supports may often remain) and the crest of the main dam being below high water mark, the surplus water escapes freely.

In the following chapters the varieties of dams more practically adapted to the wants of mill-owners in our own country will be mainly considered—including log and frame dams, embankments, crib-work, and their various combinations. We accompany each chapter (with the exception of the 1st and 2d) with a full page engraving, in order to present to the reader more clearly the suggestions we desire to offer. The methods of construction above described are chiefly useful for large establishments and corporations, with whom the matter of expense is not a vital consideration. Our next inquiry will be how the same practical reliability may be obtained, on a smaller scale and with the most moderate outlay.

CHAPTER II.

MATERIAL AND FORM OF DAMS.—*Continued.*

In many localities where stone is not readily obtained—which is the case in a large portion of the Western States—frame dams are the

cheapest substitute, and if properly constructed serve their purpose in the most satisfactory manner. If the stream has a firm and level bottom, the frames, which are made in a triangular shape, resembling a harrow, may be placed directly on the bed of the river, without any intervening foundation. The narrow end or apex is of course laid up the stream, and the frames placed in a line extending from bank to bank, with a space of three or four feet between them. The upper side being then planked the whole length of the dam, an inclined plane is presented to the current on the up stream side, and if the frames are substantially built the pressure of the water will be firmly resisted.

On a soft or irregular bottom, where a heavier foundation is required, the following plan is the most economical, and requires comparatively little labor. Three tiers of timbers running parallel to each other across the stream are placed at the foundation of the dam, one tier at the lower side, one at the upper side, and the third midway between them. Posts are then framed into the lower and middle tiers of timbers, those on the lower tier being of a height nearly equal to the top of the rafters at the crest of the dam, and the top of those in the middle tier being in range with the former and the foot of the rafters. Two upper tiers of timbers are framed upon the posts thus erected, and the rafters, which should be slightly notched at the point where they rest upon the timbers, are thus firmly supported at the head and foot and in the middle; and the planking being well fastened to them, a strong and serviceable dam is the result, with but moderate outlay either of money or labor.

The best form of dam, whatever be the material of which it is constructed, is that resembling a bow, with the arch up-stream, as described in chapter I; but this method of construction is seldom followed in frame and log dams, the straight line calling for much less labor and care, as well as less material, the distance being of course less than when a curve is made.

A cheap and substantial dam may be made, where timber is abundant, by laying a foundation of logs of considerable size, which are placed lengthwise of the stream and close together, forming a sort of corduroy road, extending from bank to bank. If the bottom is soft, the logs should be carefully fitted down and adapted to the inequalities of the bed, and if placed as deep as possible they will be less liable to decay by exposure in time of low water. The breastwork of the dam is built near the up-stream side of this foundation, the logs extending from under it down-stream, and serving as an apron to receive the waste water as it comes over. The rafters and coverings of the dam form an inclined plane on the up-stream side, and extend over the upper ends of the logs, protecting the foundation from being undermined by the water working beneath it.

In a region well timbered, and where the stream has a rock or other solid bottom, a log dam of the following description has advantages in point of cheapness, strength and durability. A series of large logs are placed in line, one at the end of another, at the down-stream face of

the dam, the loose rubbish being carefully cleaned out, and hollow places filled with short logs to support the main foundation firmly. The logs used for the foundation tier should be as long and large as can conveniently be procured. A series of short logs are then laid upon this tier, with their butt ends resting on the foundation logs and their top ends on the bed of the river, pointing up stream, the distance between them being six or eight feet. Upon these a second tier of long logs is placed, parallel with the foundation tier, but a little farther up stream. A second set of ties is laid with the butt ends on the second tier of logs and the top ends on the ground beside the first set. This second set of ties being a trifle shorter than the first, room is left to place a log of moderate size across the ends of the first ties. This will serve as a support for skids upon which to roll up the third tier of large logs. The logs should be notched where they cross and the ends resting on the ground firmly secured in order to impart the necessary strength to the whole structure. If properly built, the front of the dam will rise considerably faster than the rear, and will at the same time incline up stream, so that its form will resemble a portion of an arch, the foot of the ties being the center and the breast of the dam the circumference. Beside the series of large logs in front, a second and even a third series of smaller size, running parallel with it across the stream, may be placed in the angles formed by the ties, which should be notched where they cross the logs; and the three series of logs should range in height so that the covering of the dam will form an inclined plane—not too steep for the length of the incline, or the whole fabric may slide down stream when the pressure of the water is brought to bear. Either logs or rafters may be used in constructing the covering. If the former, they should be close together, and chinked with moss, pounded cedar bark, or other suitable material. If rafters are used, they may be placed about three feet apart and planked crossways, the thickest planks being used at the bottom and at the crest of the dam.

As a matter which may interest the reader, we give, before closing this chapter, a brief account of the method in which a broken dam in the western part of Indiana was repaired some time since, after repeated unsuccessful attempts. The dam referred to was built of logs, brushwood, etc., and the bed of the stream was a treacherous quicksand—perhaps the most difficult kind of bottom upon which to obtain a secure foundation. The breach was nearly in the centre of the dam, and not less than forty feet wide; and the deep and swift current which rushed through it defied every effort to gain a point of support from which to work. Various expedients were tried, even to throwing huge boulders into the stream, which were carried along by the force of the water and rendered of no avail. Several millwrights and engineers coasted in skiffs about the place for two or three days, looking for some base of operations, but entirely without success. At length one of them, having pushed his explorations along the banks a mile or more up stream, discovered a huge tree, with an extraordinary breadth of

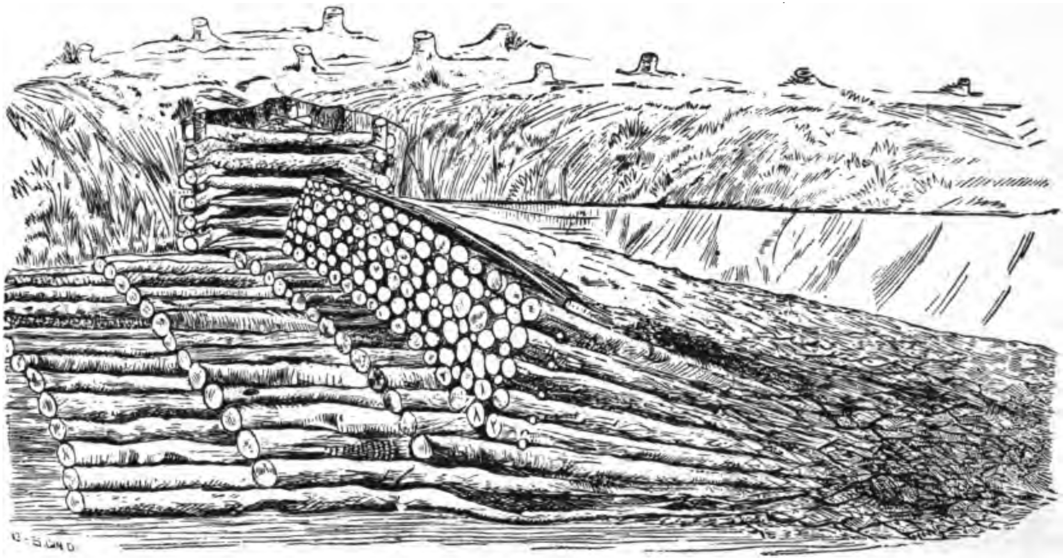
branches, near the water and leaning toward it in such a way as to suggest that it might possibly be launched into the stream. Other trees near it were felled and leaned against standing trees so as to serve as a kind of skids, and by dint of two or three days' patient toil, in which the use of windlasses was found necessary, the tree was at last guided down the stream butt foremost, and lodged in the gap at the broken dam. The expedient proved completely successful, for although a mighty cracking and splintering of boughs ensued, the stout branches held fast on the sides of the dam, and a beginning was thus made from which the necessary repairs were effected with comparative ease.

CHAPTER III.

LOG DAM FOR SOFT OR SANDY BOTTOMS.

In a country where timber is abundant, a log dam is the most economical, affording, if properly built, an ample degree of strength and durability at comparatively small cost aside from the labor involved. It is adapted, moreover, to river beds which are of too yielding a character to afford a solid foundation for a stone dam. Our engraving reproduces in all its essential features a drawing made in our office for the construction of a dam in the State of Texas. It is adapted to all localities where timber is not too costly, and especially to streams which have soft and sandy bottoms. In the engraving the dam is shown as if cut into at the middle of the stream, the further half being represented, with the crib or pen built into the opposite bank.

The dam here represented may be literally described as a "brush and timber dam," though it comes under the general head of log-dams, the main portion of its structure being of that character, while saplings of any size may be used in making it compact, and brush, clay and boulder stone for filling on the up-stream side. The process of constructing this dam is essentially as follows: Cut trees of eight or ten inches in diameter, lopping off the limbs on what will be the top and bottom sides, when the logs are placed in position. Start the first layer (forming the foundation and front of the apron of the dam, and projecting down stream as shown at the extreme left of the cut) placing the logs side by side with the tops up stream, the lower or butt-ends being about fifty feet below the point where the dam is to be raised. Having completed this, fall back about twenty-five feet and place a second layer of logs side by side as before, the limbs being carefully lopped off on the under and top sides. Having now two layers or courses of logs reaching from side to side of the stream, start a third layer twenty feet back of the second, and carry it across the stream in ame manner as the others. The fourth course, five feet back of the



LOG DAM FOR SOFT OR SANDY BOTTOMS.

third, completes the series of successive and overlapping tiers of logs constituting the foundation of the dam and forming the apron. With this last course, you begin raising the dam, using for the purpose trees and saplings of any convenient size, and all the while filling in compactly, especially toward the up-stream extremity of the dam, with brush and clay. If boulder stones are readily accessible they should be thrown in along with the clay.

The successive courses of logs should now be laid on in such a way that the face of the dam will present a steep slope, the crest being about two feet farther up-stream than the point at which the dam rests upon the apron. At nearly every course it is well to lay binders lengthwise across the stream, pinning them to the largest logs beneath them. The ends of these binders, which may be three or four inches in diameter, are shown in the cut. They should be placed from two to four feet back of the face of the dam. Having reached the crest of the dam, a top binder is pinned on as solidly as possible, a pin being driven wherever there is a chance for it to hold. If convenient, two or even three binders may be employed, in which case they should be firmly secured to each other and to the upper tier of logs. The dam should be filled in on the surface, from the crest back to the extreme up-stream tips of the trees, with fine brush and clay. For this purpose, trestle work may be built out over the stream and planks laid on to serve as a track on which to wheel the dirt out upon the dam. Throughout the whole work, care should be taken to lop the branches from the top and bottom sides of the trees, and the butts of the trees should invariably be laid down stream. The dam should be made in the form of a semi-circle or half-moon, arching up-stream.

To secure the ends of the dam, a log-pen should be built at each bank, (one of which is shown in the cut,) extending back into the bank as far as it can conveniently be carried. Each pen should be chinked from the inside and filled with clay; or if stone is plenty it may be used instead of clay for filling the pens, which will not then require to be chinked. If clay is used it should be packed in as tightly as possible to prevent it from working out.

It has been found that a dam of this kind will settle about eighteen inches the first year, for which due calculation and allowance should be made. After that time, it will remain nearly stationary. It is cheaper, in a favorable locality, than a frame dam, and has an important advantage in the fact that it will hardly ever wash out. It is almost impossible to build on a quicksand bottom a frame dam that will stay in, as the experience of many mill-owners has shown. The use of piling cannot be recommended, as the water forms small whirlpools around the piles, and will in time wash out the earth clear to their bottoms.

It should be remarked that in building a dam of this kind, unless the stream is nearly dry, it will be well to leave a passage through which the water may escape while the building is going on. This need not usually be done until the apron is completed, and perhaps one or two

courses of the upright part of the dam laid on; but after that it will be expedient to leave a space or channel near the middle of the dam for the water to pass through until the rest of the dam is finished, when the gap may be closed up.

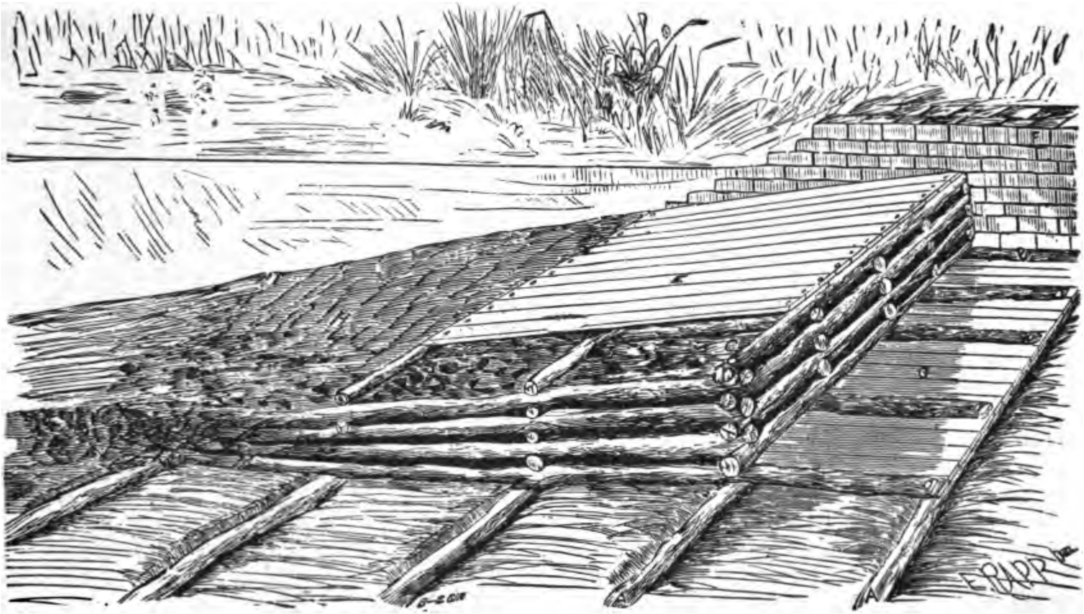
CHAPTER IV.

A SAFE AND ECONOMICAL DAM.

We give in connection with this chapter an illustration representing a style of dam which can be confidently recommended for its durability, and which involves no excessive outlay either of money or labor. It has some points of resemblance to the log dam described in our last chapter, but the dam referred to is particularly suited to a region where timber is abundant, while the one here shown does not require so ample a supply of that material. The abutments of this dam, it will also be observed, are built of stone, instead of crib-work, as in the former case. Crib-work, however, can be substituted if more convenient; or if stone is used, cap-rock or rubble will answer the purpose, if compactly laid and filled in with earth solidly in the rear, nearly as well as more costly building stone.

The construction of this dam is shown very thoroughly in the cut. Its qualities of firmness, compactness and durability adapt it to any sort of bottom, whether it be sand, soft mud, gravel or rock. The first step in the process of building it is to lay the foundation logs A A, which extend across the stream, being spliced if necessary, to obtain the requisite length. They should be imbedded in ditches crossing the stream transversely, and of sufficient depth to bring the upper surface of the logs nearly on a level with the bed of the stream. One of these logs is laid at the foot of the apron, another at the point where the dam is to be raised, and the third, fourth and fifth farther up stream, as shown in the cut, the distances between them being six or eight feet. The ends of these logs should project some distance from the sides of the dam into the bank or under the abutment. The weight of the abutment resting upon them will have the effect to hold the dam in its place and prevent it from being lifted or moved forward by the force of the current.

The second series of logs, B B, are laid across the first course, lengthwise of the stream, and about six feet apart, the butt ends resting upon the lower log of the first course. The dam is then raised at the second log of the foundation, which is six or eight feet from the front log, the intervening space being occupied by the apron of the dam. A log of considerable size is laid down directly above the foundation log, and notched to the logs B B wherever they cross. A smaller log may be laid in like manner above the third foundation log, and also at the



"A SAFE AND ECONOMICAL DAM."

fourth if desired; as these cross-logs or binders, which should be put in with considerable regularity, especially at the face of the dam and near it (as shown at D D) will serve to support and hold together the whole fabric. The alternate courses of logs having been carried up to the height of about five feet at the face of the dam (which should be nearly perpendicular) and sloping back gradually as shown in the cut, the crossing of the logs will form cribs or chambers, as at C, which are to be filled with stone or gravel. Stone is to be preferred if conveniently at hand, but gravel answers the purpose nearly as well. The binders on the top of the dam, crossing the stream, are to be firmly fastened to the logs upon which they rest—those at the crest of the dam and at the lower edge of the planking being secured by bolts, which pass through all the successive logs below them to the very foundation of the dam. Except at these points it will be sufficient to fasten the binders with long pins to the logs beneath them. The planking E already referred to extends from the crest of the dam about twelve feet toward the up-stream end, and serves to protect the front of the structure from damage by ice or driftwood. The spaces at H, at the rear of the dam, below the planking, should be filled with stone or gravel.

The abutments F (only one of which is here shown, as our engraving comprises but half of the dam, giving a front, top, and sectional view) are built, as already stated, upon the ends of the foundation logs projecting from the sides of the dam, aiding thereby to hold the structure in its place. The abutment represented in the cut is of solid masonry, good building stone being the material employed; but it may be more cheaply constructed, either of rough stone or crib work, as described in the introduction of this chapter.

The apron of this dam should be planked between the projecting logs, as shown at G, the planks extending back under the first transverse log which begins the face of the dam.

It will be manifest from the nature of its construction that no part of this dam can be moved from its place without the entire fabric going with it. The different portions being firmly connected and secured to each other, the structure must go out bodily or not at all. The great breadth of the dam at its base is one of its strongest advantages, preventing it from being undermined by the current—a danger which constantly threatens a dam with a narrow foundation, let it be ever so strongly built. It is also to be observed that the amount of timber required in building by this plan is very moderate, being much less than is often used in dams which do not possess nearly so much actual strength as is here afforded. As a practical example of the reliable character of this dam, we may here remark that one of the publishers of this work, having had two costly dams of cut stone carried away from the same site by high water, finally built one according to the plan here described, at a total cost of $700, and found it perfectly safe, the floods of four successive years, some of them extremely violent, having failed to carry away any part of it, or inflict any material damage. Neither of the two stone dams which preceded it stood over

eighteen months, the bottom being of the sandy and treacherous nature to which a great part of the difficulty involved in the science of dam-building is to be attributed.

CHAPTER V.

A HOLLOW FRAME DAM.

We present in this chapter an illustration of a hollow frame dam adapted to a country where economy in timber is necessary. It offers an equal degree of security with the log dams previously described, at the same time requiring far less material in its construction. The dam here represented is built upon a solid rock bottom, but with slight modifications is adapted to streams with a soft or sandy bed, as hereafter explained.

The first step in the construction of this dam is to lay the foundation blocks A A, each of which is a stick of timber ten inches square and about four feet in length. Three rows of these blocks are to be laid across the stream, one at the face of the dam, one at the up-stream extremity, and another midway between them. The distance between the centers both ways—across the stream and from one row to another—is eight feet, giving three blocks or bearings to each bent of the frame work. Three additional blocks are placed in the front row and twelve in the rear row to receive the bolts by which the dam is fastened to the rock. Upon these blocks are now laid the mud-sills B B, which form the immediate foundation of the dam, consisting of logs about sixteen inches in diameter, hewn on the upper and under sides so as to give a t ickness in that direction of thirteen inches. These are laid across the bed of the stream in three tiers, one for each row of blocks. Where jhints occur, a two-feet splice should be made, and the two ends firmly ponned together. The end of the front sill at each bank should project inito the abutment about fifteen inches; while that of the second or middle sill projects an equal distance just behind the up-stream wall of the abutment, the centre of which is near the front sill, bringing part of the abutment against and the other part below the dam. The front sill has three bolts passing through it, one at each splice, an extra block being placed underneath as already stated. The up-stream sill has twelve bolts, under each of which is a block, in addition to the blocks on which the bents of the frame-work are to rest. The bolts should be $1\frac{5}{8}$ inches in diameter. Each one of them passes through the sill and block down into the rock, which it penetrates about three and a half feet, making the total length of the bolt five and a half feet. The bolt is made after the hole has been drilled, the necessary length being ascertained by careful measurement. A "stoved head" as it is called, is given to the bolt, and a washer placed underneath the head,

which is drawn tightly down by the tapered shape of the head. In order to prevent any possibility of the bolt working loose, the lower end is split five or six inches up, and an iron wedge inserted. When the bolt is driven down, the wedge, coming in contact with the rock, is driven up, and spreading the point, holds the bolt firmly in its place. Fine wet sand afterward put in will make it perfectly tight and solid, being as effective for this purpose as lead or cement.

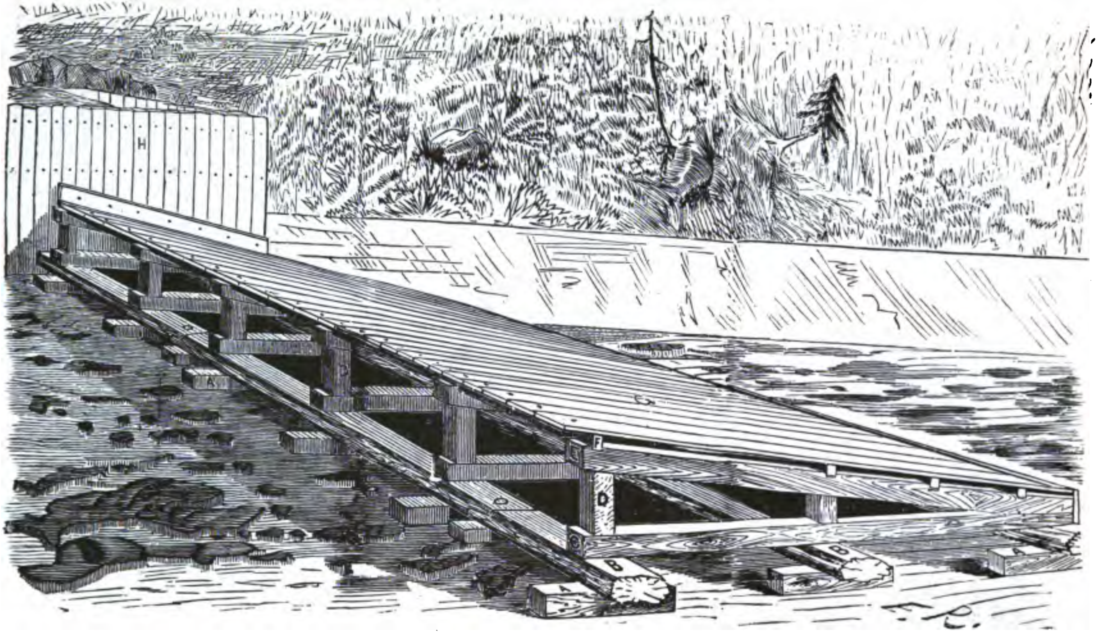
In drilling the hole in the rock, an ordinary stone drill slightly smaller than the hole to be made, is employed, and is put down through the sill and block, which are previously bored and placed in position.

The bents of which the frame-work of the dam is constructed, and which come next in order, are built throughout of timbers ten inches square—the same size of material being used in the lower horizontal pieces C C, the uprights D D, and the upper pieces E E, which form the slope of the dam. The length of the lower timbers is sixteen feet, and that of the upper timbers the same, the effect of which is to give the face of the dam a slight inclination up stream. The lower timbers are framed into each sill, a gain being cut two inches deep, and the timbers secured with a dove-tail key driven to the side of each bent. The upright posts connecting the upper and lower timbers of the bent have a length of two feet three inches in the clear at the face of the dam, and half that length at the middle sill; and they are to be mortised into the upper and lower timbers in the same manner as in the framing of a house. The bents are the same distance apart between centers as the blocks under the sills—eight feet, and the distance from the front to the middle upright is the same. The upper and lower timbers of each bent are hewn obliquely or beveled at the up-stream end so as to fit snugly together and give a combined thickness at the extremity equal to one piece.

The last step in the building of the frame is placing the ties F upon the top of the structure, extending transversely across the stream in the same direction as the sills. There are five series of these ties, one over each sill and one between. They should consist of timbers 4 by 7 inches and lie on the narrower side. Each tie is let into the upper or inclined timber of the frame wherever it crossess, the depth of the gain being one and a half inches, giving the tie five and a half inches thickness above the frame. The gain is cut into the frame at right angles with the upper timber, the ties being thus slanted slightly up stream and presenting a level surface for the planking. The forward tie is let into the frame piece about four inches from the end, in order to give sufficient strength to the gain to prevent it from breaking out.

The whole upper surface of the frame is now planked over. The planking, which is strongly spiked to the ties, should be one and a half inches thick, and the wider the better, as the fewer the number of joints, the more secure from leakage will be the covering of the dam. A greater thickness of plank than that given will increase the liability to rot, as the wood is wet on one side and dry on the other.

The abutments, as already stated, extend but half way from the face



A HOLLOW FRAME DAM.

to the up-stream end of the dam. To protect the exposed portions of the sides, the dam is enclosed with stout upright planking from the middle sill to the up-stream end, the ends of the planks resting on the rock bottom. In like manner, the rear of the dam is closed with sheet piling extending from bank to bank, closely matched and of sufficient height to meet the planks which cover the top of the dam, the lower ends of which are footed by the piling, which extends to their upper side and is flush with the surface of the dam.

The abutment is built of timbers fifteen to eighteen inches in diameter and is eleven feet square. The logs are hewed on one side to give a face to the abutment. The first or foundation timbers are laid in the same direction as the sills of the dam, transversely to the stream, the lower one about three feet below the face of the dam, and the upper one just below the middle sill, which it touches and helps to hold in position. The first cross piece on the side toward the dam is laid over and across the end of the front mud-sill, which extends beneath it, as already stated, about fifteen inches into the interior of the crib. The up-stream end of the cross piece reaches to the middle sill of the dam. The timbers of the crib are notched and saddled where they rest upon each other, and the structure is thus firmly held together. The ends of the first two ties on the surface of the dam extend to the crib, and the third tie passes directly behind it in the same manner as the center sill below. The crib is filled up with rough stones or coarse gravel, and covered with upright planking on the upper side and on the side against the dam. A joist, I, two by ten inches, is spiked against the crib along the top of the dam from its crest to the up-stream corner of the crib.

The dam here shown is ninety-three feet long and its total hight from the rock bottom to the surface of the planking is six and one-half feet. There are eleven bents in the complete dam, only half of which is shown in our engraving. The dam here represented was built by Messrs. Bookwalter & Claypool, of Attica, Indiana, to furnish power for a large and very complete flouring-mill erected by them, in which three Leffel Double Turbines were placed, with all other necessary machinery, furnished by the same establishment. The design of the dam, which was drawn in the office of James Leffel & Co., can be adapted with some alterations to a stream having a soft instead of a rock bottom. For that purpose, it would be necessary to lay a foundation of two and one-half inch plank, instead of the blocks, for the sills to rest upon. These planks should be laid lengthwise of the stream, and project ten or twelve feet below and an equal distance above the dam, making a total distance of about forty feet. As it is difficult to obtain planks of this length, the foundation may be laid in two sections, the planks in each having a length of twenty feet. About midway between the breast and the up-stream end of the dam, where, if the planks are twenty feet long, a joint will occur, a wide sill should be placed beneath them, upon which the ends of the planks can be firmly spiked. At the down-stream end of the planks, constituting the edge of the apron, a light sill or binder should be placed underneath—not to support, but rather

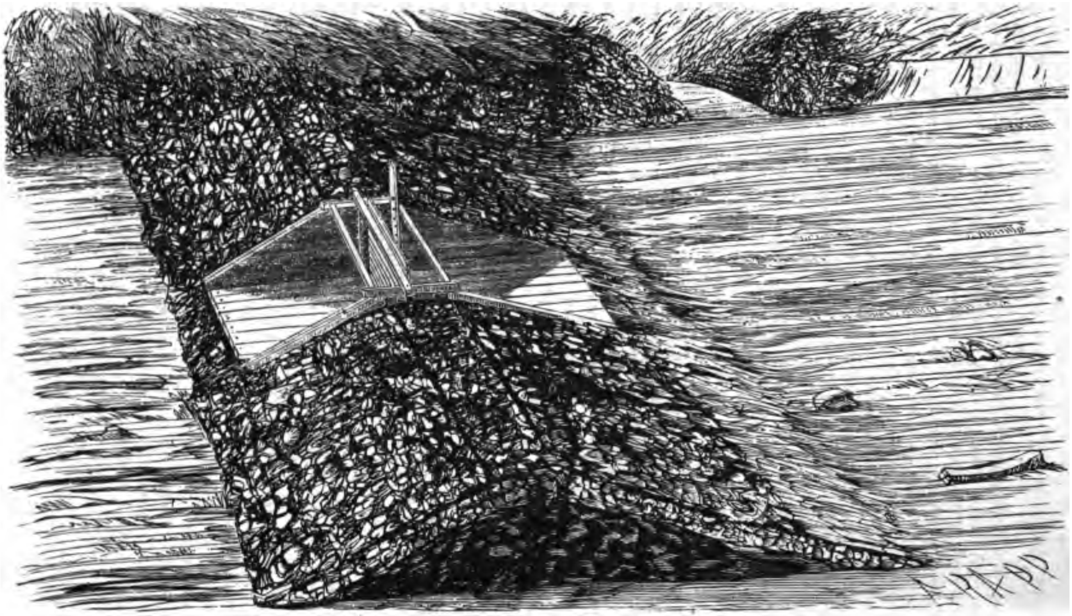
to hold together the planks. At the up-stream end, the planks will be simply imbedded in the soil, and the planking at this point, and the whole back of the dam, covered with gravel, sand and dirt. A layer of brush at the bottom of this covering will make it hold all the more firmly to the bed of the stream.

CHAPTER VI.

A RIP-RAP DAM.

The conditions of cheapness in the construction of a dam are changed by every change of locality. In one section, where material of a suitable kind may be comparatively abundant, while labor is scarce and commands high wages, economy is consulted by making the work of building as short and simple as possible, even if the material used is not the cheapest which could be found. In another district, or under different circumstances, workmen may be easily obtained at a very moderate rate, and the mill-owner may in this case save money by putting an extra proportion of labor instead of expensive material into his dam. Our engraving herewith given illustrates a kind of dam wholly distinct from any which we have before presented. In some portions of the country it would be difficult to find stone enough for its construction at any price—and it is not intended, of course, for the demands of such localities. In other sections, the earth and stone of which it is composed would cost almost literally nothing, and it has the further advantage of requiring no skilled labor in putting it up, except in building the chute and waste gate, and in the laying out and general superintendence of the work.

The construction of a "rip-rap dam," which is the term commonly applied to a dam of the description here shown, is begun by throwing an embankment of earth across the stream (space being left in the middle of the stream for the waste-way or chute), carrying it up to a hight of about eight feet in the center and sloping it as shown in the cut, quite steeply on the down-stream and more gradually on the up-stream side. The dam here illustrated has an extent between the foot of the up-stream and that of the down-stream slope, of from thirty to forty feet, and from one bank of the stream to the other of a little over seventy feet. Of the latter distance, twelve feet in the middle of the stream is occupied by the chute (in which the waste-gate is placed as hereafter described), leaving a distance of thirty feet on each side, from the frame-work of the chute to the bank. It is not intended, of course, that the water should at any time flow over a dam of this sort, the escape of surplus water being provided for by the chute. The two slopes of the embankment do not meet at the top in such a way as to form a sharp ridge or crest, but the summit is leveled off so as to give a nearly



A RIP-RAP DAM.

flat surface about four feet in width, extending the whole length of the dam from each bank until it reaches the chute.

In constructing the embankment, the framework of the chute is to be set in position and strongly planked on the interior side, where the water is to pass, before the earth is filled in at that point—except that a fill about two feet in depth is made on which the floor of the chute is to rest. This floor is laid upon a frame of heavy sills and cross-timbers, the planks of which it is composed extending lengthwise of the stream, and projecting at the down-stream end some eighteen inches beyond the face of the dam, in order that the current of water, as it issues from the chute, may be carried beyond and clear of the embankment beneath. The tendency of the water to wash away the foundation of the dam is thus avoided. This is an important point, as the result of neglect in this particular will be the speedy undermining of the chute and caving in of the wall of earth and rock on either side.

The earth-work having been completed, the dam is now to be "rip-rapped" from end to end. This process consists in laying two courses of stone, one above the other—ordinary cobble-stones being a suitable material for the purpose—over the whole surface of the embankment. The stones are placed on their edges, in the manner in which a gutter is paved, and laid as compactly together as possible, so as to give the entire dam a strong and durable face on both slopes and along the crest. The united depth of the two courses of stone will be about twenty inches. If three instead of two courses are laid, additional strength will be gained, and the dam will be all the more secure from the effects of any accidental inroad of water. The rip-rapping should not be confined to the dam itself, but extend along the banks on both sides of the stream, a short distance above and below the dam, as shown in the cut. This will prevent the banks from being worn away or washed out, and protect the dam from injury, to which it would otherwise be constantly liable.

The up-stream slope of the dam is covered with earth from the base about two feet upward, reaching to the floor of the chute.

Our engraving represents, in addition to the dam, the inlet and part of the channel of the mill-race, on the further bank of the stream. The corners of the banks at the point where the water enters the race should be rip-rapped in the same manner as the dam, to secure them from being washed away and caved in by the continual action of the current. The exact distance to which the sides of the race at this point should be covered with stone will be determined by the shape of the bank, character of the soil, swiftness and force of the current, and other considerations which vary in different localities. The matter will be easily regulated by the exercise of a fair degree of judgment; but in general it is best to err, if at all, on the safe side. A little extra precaution, resulting in perfect security, is better than a falling short which may lead to damage and destruction in time of flood.

The construction of the chute and waste-gate is a matter in which, of course, some measure of skill in the carpenter's and millwright's trade

will be in demand. The heavy timbers required are the sills and cross-timbers of the floor, the upright posts, the inclined or slanting beams which follow the direction of the slope of the dam up and down stream, and the timbers connecting them at the top, which will be as long as the crest of the dam is wide. The posts are mortised into the sills below and into the beams above, and their lengths are so arranged as to give the proper slant to the inclined beams, parallel with the face of the dam.

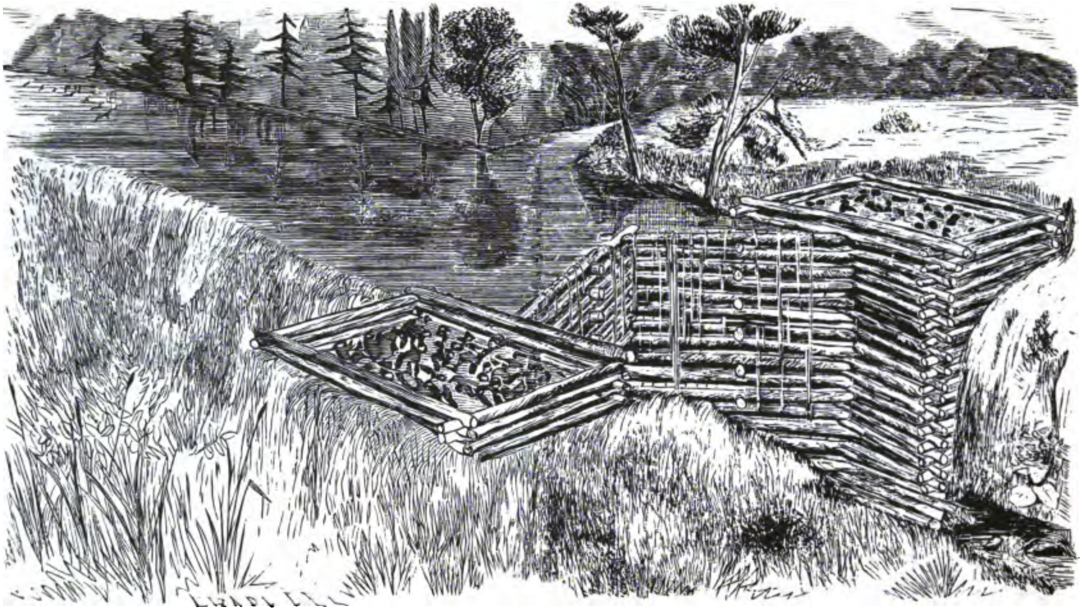
For the construction and operating of the gate, a number of methods are in use. A very simple arrangement is that in which the gate is raised and lowered by the use of a lever inserted into holes in the standard to which the gate is attached. A chain and windlass may also be used, the manner of their application being so obvious as to require no minute description. Still another form of gate is found very useful, in which the gate is made in sections, each section swinging on a horizontal axle resting on journals near the bottom of the gate, so that it can be let down like the tail-board of a cart when desired, and raised with equal ease whenever necessary. The division of the gate into sections, or as it were into several narrow gates, each acting independently of the other, is found expedient on account of the great force it would be necessary to apply to raise and lower the entire gate in the manner described. The gates fall in the up-stream direction, their own weight assisting the process when they are lowered, and the force of the current helping to raise them—sometimes more powerfully than is desired—when the chute is to be closed.

CHAPTER VII.

A CRIB DAM.

We present in this chapter an illustration of a dam peculiarly adapted to streams which have a comparatively narrow channel, with a high bank on each side—although the latter condition is not indispensable, as any deficiency in this respect, if the shape of the country is not extremely unfavorable, can be made up by constructing an artificial levee or embankment. The structure of this dam is of the nature of crib-work throughout, logs being the material used in every part, although stone, gravel, clay and brush are employed in filling at various points, as hereafter described.

The dimensions of the dam shown in the cut are nearly as follows: length of span, fifty feet, the logs in each of the two sections being about thirty feet long, giving ample margin for notching at each end; cribs on each side twenty feet square, the logs of which they are built from twenty-two to twenty-five feet long and the hight of the cribs from twenty-five to thirty feet. The dam itself is twenty-five feet high, the



A CRIB DAM.

cribs being carried up three or four logs above the top of the dam.

In building a dam of this description, the whole structure, including both the cribs and the V shaped connection between them, are begun and carried up together. The apron, however, is first put down, consisting of a layer of logs placed closely side by side from bank to bank, with the butt ends down stream, and the limbs lopped off up to the point where the dam is to rest upon the apron. Above this, the limbs may be left on the trunks, as they extend into the earth which is filled in above the dam. The front of the apron should extend three or four feet forward of the cribs, as shown in the cut. The logs used in building the apron, and also the cribs and the dam itself, should be, if possible, at least one foot in diameter, in order to give the proper degree of weight, strength and solidity to the fabric.

Having completed the apron, the next step is to lay the foundation of the wings and central portion of the dam. The first log of the crib on each side should be firmly pinned to the apron; or the foundation of the crib may be laid two or three feet deeper than the apron, in which case it will not be necessary to fasten them together. The cribs are each to be set into the bank, which will thus enclose them on three sides, as appears in our illustration. Thus situated, it is scarcely within the bounds of possibility for the cribs to be moved from their position; and if their connection with the dam is made firm and secure, the strength of the fabric, aided by the peculiar shape which it presents to the current on the up-stream side, will resist almost any conceivable pressure of water.

In building up the cribs and the dam, the logs are to be notched and saddled wherever they meet—that is, at the four corners of each crib, at the points where the timbers of the dam enter the crib, and at the middle of the dam where the two sides of the angle or V intersect. This angle is of course pointed up-stream, the proper distance from the center or place of intersection to the down-stream edge of the apron being about twenty feet. The pressure of the current upon the harrow-shaped structure thus presented to it will of course tend to spread the two wings or cribs apart; but if the latter are well grounded, filled and supported, and the logs in every part of the dam carefully notched upon each other, the force of the current will have no perceptible effect.

Binders are to be inserted in each half of the dam as the work progresses, one for every second course of logs being sufficient, although one for each course is still more effectual. Small trees or saplings may be used for this purpose with the limbs and brush left on, the butts resting between the logs of the dam and the tops forming a part of the filling on the up-stream side. In the engraving, the ends of these binders may be seen between the courses of logs forming the V, the tops of course being covered up and invisible.

The cribs are to be filled with stone and gravel, and if these materials are scarce, a moderate proportion of clay may also be introduced. The up-stream side of the V is to be covered with upright planking, which will extend from the top log down to the apron. Planks ten

inches wide and two inches thick are suitable for this purpose, and they should be placed close together and either pinned or spiked to the logs, as convenience may dictate. The planking is cut away at the points where the binders occur, sufficiently to admit the ends of the binders, which rest upon the horizontal logs and are notched to them as already described.

The filling on the up-stream side, against the planking, completes the building of the dam. For this purpose, any convenient material may be used, whether stone, gravel, clay or brush, or all together. The filling should slope gradually from the crest of the dam, extending up stream a distance of not less than twenty-five feet, in order that all risk of the washing or undermining of the dam may be avoided.

If the banks of the stream are too low to enclose the cribs to a sufficient hight to make them secure in their position, an artificial embankment must be constructed, covering three sides of the crib and extending from the stream until it reaches ground of the same hight as the top of the dam. This embankment should be made wide and substantial, and compactly built of stone or earth. It is important that the material should be of such a nature that the water will not penetrate it, as the destruction or serious injury of the dam may occur in consequence of a very small outlet. The main force of the stream is brought to bear, of course, upon the dam itself; but in time of high water there will be more or less pressure upon the levee, which should accordingly be made as secure as circumstances will allow.

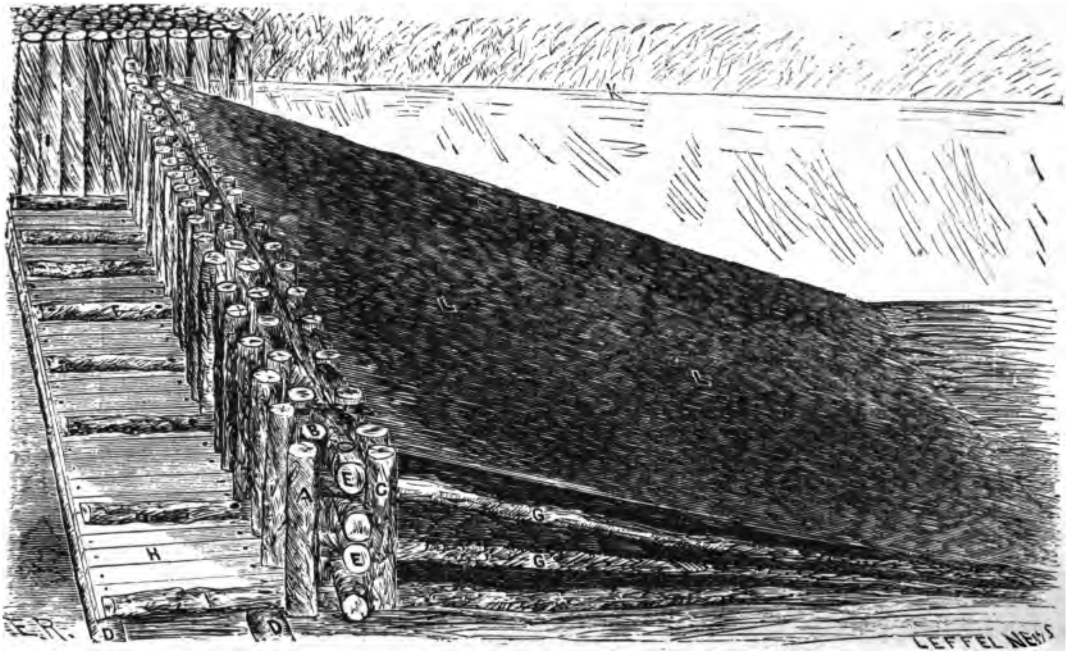
Our illustration shows, also, the entrance of the race above the dam, on the left bank of the stream.

The dam above described is adapted to any sort of river-bed, whether it be rock, sand or clay. The shape of the banks is a more material point than the nature of the bottom, especially if it is desired to raise the dam to a hight equal to that shown in our engraving.

CHAPTER VIII.

A PILE DAM.

The dam which we illustrate in this chapter is adapted to a mud bottom or to any kind of river-bed which will afford a firm foothold for piles, and into which they can be driven to the necessary depth. The first step in the process is the preparation of the piles, which should be of oak if convenient, ten or twelve inches in diameter, and from twelve to twenty feet in length, according to the height it is intended to give the dam, the nature of the bottom, and consequently the depth to which it is necessary to drive the piles. The taper at the lower end should begin two or two-and-one-half feet from the point. In using the pile-driver in setting the piles it will be found that the



A PILE DAM.

force of the successive blows will after a time have the effect to split the pile at or near the top; and to prevent this a ring should be placed over the top of the post. This ring is made of bar iron three-fourths of an inch thick and from two-and-a-half to three inches wide, the ends where they meet to form the circle being welded as strongly as possible. It is also expedient to champer or bevel the inside of the ring so that it will go on with the wider opening downwards, the object being to make the ring compress the top of the pile in such a manner that when it is desired to remove the ring it will come off easily. Care must be taken not to champer it at too great an angle, or the post will act upon it like a wedge and the ring will burst before the driving is completed. As this accident is liable to happen in spite of every precaution that can be taken, it is well to have several rings made before beginning the work, so that while one is taken away for repair another may be used and the driving go on without interruption.

For a dam like the one here illustrated, the piles are driven eight or nine feet into the ground, leaving from six to eight feet above for height of dam; but where the bottom is sound and firm the posts need not go in to so great a depth. There are three rows of piles shown in our engraving, the two front rows, A and B, being close together, but alternating so as to "break joints," and the second and third rows, B and C, being far enough apart to admit a horizontal layer of logs E E between them. A dam may be built with but two or even only one row of piling, and possess sufficient strength for any ordinary test. If only one row is planted, logs and brush should be piled up behind it on the up-stream side so as to make the dam tight and break the immediate pressure of the current. The horizontal logs E E should be of about the same diameter as the piles; and between them, at intervals, are inserted the butt ends of the binders G G, which are logs or poles from thirty to forty feet in length, extending from the piles up stream and being covered with the filling. The upper horizontal log E is pinned, as will be seen in the cut, to the end of the binder below it; and this should be done at frequent points along the whole extent of the span.

The apron H has a foundation of heavy sills D D, for which large logs should be selected, laid transversely across the stream, and spliced and firmly pinned where two ends meet. Cross logs F F are laid upon these, extending up stream between the piles, and having a length of from ten to fifteen feet, or whatever may be necessary to prevent the water, as it comes over the dam, from striking beyond the apron and washing out the river bed. The planks H are laid parallel with the cross logs F and firmly spiked to the sills D D.

The crib I is a hollow square composed of piles driven down in the same manner as those of the dam, but of greater length above the bed of the stream, making the top of the crib from two to four feet higher than the dam, according to the height and nature of the bank. These piles, as will be seen, are placed close together; and the dam should meet the crib at a point a little farther up stream than the center of

the crib. At K is shown the water-line when the dam is full to the crest; and at L is indicated the filling, for which gravel, dirt and stones may be used, the slope extending from the crest of the dam thirty or forty feet up stream. The same material is used for the filling of the cribs or abutments, of which but one is shown in our engraving, which represents the dam as if cut in two, lengthwise of the stream.

It is of special importance that the dam should be made as nearly water-tight as possible in every part. For this purpose stones may be used in filling the holes, the size of those first put in being sufficient to prevent their passing through, and smaller stones being thrown in after these. The same process is of equal benefit in the interior of the crib, where there is considerable liability of washing out. Hazel brush cut fine and closely packed in is also recommended for this purpose, the only objection being that it is subject to decay in course of time.

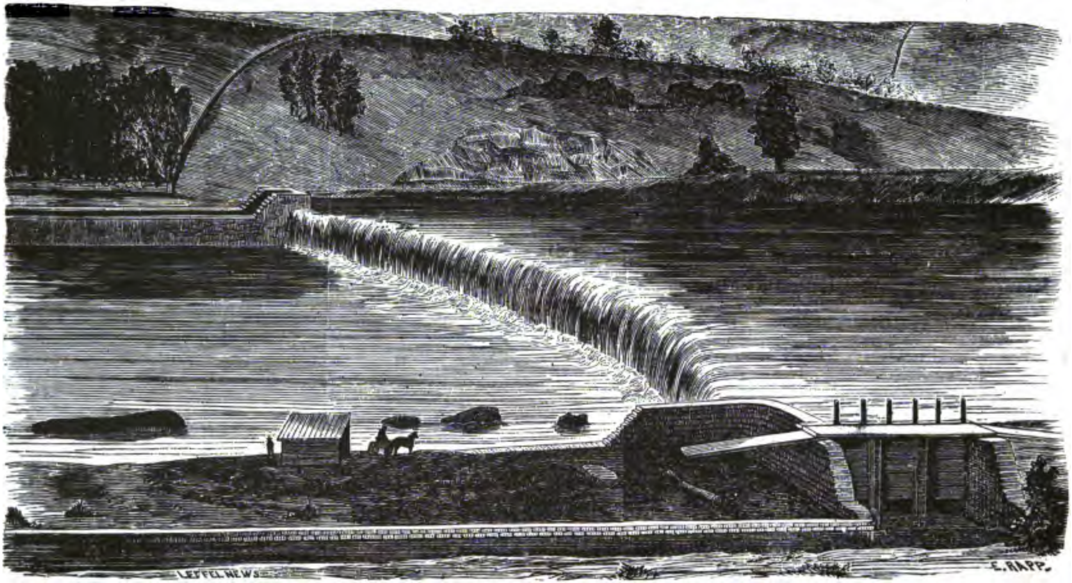
Upon a bottom of suitable character, a dam built upon this plan will be found very substantial and reliable. It is of course not adapted to localities where quicksands occur at the bed of streams, as the piling cannot in such a case be given a firm foothold.

CHAPTER IX.

THE HOUSATONIC DAM AT BIRMINGHAM, CONN.

Our suggestions on the subject of dam-building have thus far been chiefly confined to enterprises of a comparatively limited scope, being within the means of a single mill-owner of moderate capital. As this class comprises nineteen-twentieths, at least, of all the persons immediately interested in the use of water-power, it is of course entitled to the larger share of attention, and it is for the benefit of such readers that this volume is principally designed. As a variation, however, of the general plan thus far adhered to, a description of one of the most extensive works of this nature ever carried to successful completion will possess sufficient interest to reward an attentive perusal. Such an enterprise is the erection of the Dam of the Ousatonic Water Company, which extends across the Housatonic River at Birmingham, Connecticut, and which was some ten years since brought to successful completion. There are but few instances of a work of this kind conducted on so large a scale, and involving so immense an increase of manufacturing facilities.

The damming of the Housatonic River was a subject of discussion as long ago as the year 1838, and at about that time a petition was presented to the Legislature of Connecticut having this object in view. Only a low tumbling dam, however, was permitted to be built, a high one being forbidden on account of its preventing the passage of the shad—a higher value being then attached to the shad fisheries than to



THE HOUSATONIC DAM, BIRMINGHAM, CONNECTICUT.

the manufacturing interest. This compelled, also a change of the location of the dam, and ultimately it was found that half a million dollars would be required for its erection, whereupon the enterprise was abandoned. It did not again take practical shape until the year 1863, at which time the movement was inaugurated which has since been crowned with such triumphant success. The interval from 1863 to 1867 was consumed in financial and legislative preliminaries, negotiations for real estate, obtaining of the charter and capital stock, etc., the Company being organized in November, 1866. The plans and specifications were then made by Wm. E. Worthen, of New York; Henry T. Potter was engaged as Engineer and Superintendent, and the first stone was laid July 17, 1867. In August of that year, and in September, the work was interrupted by freshets. The double difficulty arising from the current of the river above and the tide below with its three feet rise and fall every twelve hours, rendered the laying of the foundation an arduous task; and it was found necessary to build coffer dams of plank, backed with earth, the water being then pumped out of the enclosed space. One of these dams was broken by the August freshet, but was speedily repaired. The stratum of rock at the bed of the river was found to dip too much to admit of the masonry being united with it, and the foundation was therefore laid on the gravel above, into which sheet piling was driven, the ends projecting upward a few feet and being encased in the stone-work. In November, four months from the commencement, about 200 feet of the dam had been built, some twelve feet above the foundation.

In 1868, the 200 feet of dam in progress the previous year was completed and 300 feet more of the foundation laid, leaving a gap of 100 feet for the passage of the stream, when a freshet swept through all the coffer dam protecting the unfinished work. This was late in the season, and the coffer dam was not restored until the spring of 1869, when it was nearly carried off a second time by a June freshet which caused two weeks' delay in the enterprise. The work then progressed until the gap in the center had been nearly closed, the water having been turned through the head-gates on the west side, when the heaviest disaster of all occurred, on the occasion of the great freshet of October 4th. The central portion of the dam had been left in the worst possible condition, the back being carried up several feet higher than the front. The water passed over this part thirteen feet deep, carrying away the coffer above and undermining and sweeping away about 160 feet of the dam. No attempt was made at rebuilding until the following year, when the coffers above and below the dam were restored, the latter being finished early in July. The removal of the water from the immense coffer below the dam was a work of such magnitude that the Engineer, Mr. Potter, devised a pump expressly for the purpose, 48 feet long, 4 feet wide and 12 inches high, with buckets or elevators attached to belts. The power for this huge elevator was furnished by a turbine wheel, enclosed in a large frame-work built on the apron at the west end of the dam, and using a portion of the water from the

HOUSATONIC DAM—(Ground Plan.)

river then flowing through the head-gates, to conduct which to the wheel a temporary flume was constructed. Geared to this wheel was a large fly-wheel 12 feet in diameter, and another 190 feet distant, driven by a rope-belt above the pump. At each end of the pump was a drum, around which the elevator-belts passed, and into which one-half of each bucket fitted. This enormous pump worked night and day for several weeks, throwing about 5,000 gallons of water per minute, and enabling the workmen to pursue their task below the level of the river. When the water had been all removed from the coffer, it was found that the full extent of the damage done by the October freshet had not been realized. It had not only swept away the central part of the dam but had cut down the river-bed south of the dam, making a hole more than half an acre in extent and 20 feet deep below the apron. This immense cavity was filled with rock and stones, the foundations laid upon it, and on the 5th of October, 1870, the last coping stone was laid. On the 14th of that month the water was running over the dam, and the enterprise was an assured success.

The Housatonic dam, thus completed in spite of the most formidable obstacles, is of solid masonry, 870 feet long, including the abutments, and 22 feet 6 inches high. The curve which it makes, as shown in our second cut, constitutes the arc of a circle having a radius of 2,000 feet. The base is 20 feet, and the front has a slope up stream of 2½ inches per foot. It is capped with blocks of Maine granite 8 feet long and 1 foot thick. The whole structure, including the surroundings, is estimated to contain 451,000 cubic feet of masonry. For the protection of the base from undermining an apron is provided, as indicated in our third cut, 24 feet long, composed of timber and concrete, and having 10-inch sills extending 8 feet into the stone-work of the dam. These sills are imbedded in concrete, and a second course of timbers of the same thickness are bolted to them at right angles. All the spaces are filled with concrete, and the surface of the apron is then laid, consisting of timbers a foot square, lying close together in the same direction as the lower sills, and strongly bolted to the timbers underneath.

On each side of the river is a canal conveying the water for use by the factories. That on the west side, which is the larger of the two, has five gateways, each eight feet square, with solid pillars of stone two feet thick between them, the bottom laid in cement and the top slabs of stone. The gates are made of oak planks, 8 by 8 inches, strongly bolted together and shutting in grooves in the stone. The canal is 60 feet wide and 14 feet deep, giving a cross section of 840 square feet, and has an overflow of 150 feet near the dam. The sides are walled with stone. In its complete state it will open 3,700 feet of factory front, or over two-thirds of a mile.

In June, 1871, the discharge of the river was ascertained to be nearly 5,000 cubic feet per second. Early in the fall the discharge was still one-fifth the above amount, in the midst of a drought which stopped nearly all establishments dependent upon water-power. The

HOUSATONIC DAM.—(Vertical Section.)

minimum average flow at the lowest stage of water is estimated at 500 cubic feet per second, equivalent, with the head of 22 feet, to 2,500 horse-power for 12 hours per day. With the ample reservoir, extending back five miles and covering nearly one thousand acres, no apprehension can exist of a lack of water.

CHAPTER X.

A PLANK CRIB DAM.

We return in this chapter to a class of dams more generally interesting to the milling community, because more applicable to the circumstances and wants of the vast majority, than such extensive structures as that described in our last chapter. For every locality where capital by the hundred thousand or half million dollars can be judiciously invested in a dam, or is at command for such a purpose, there are hundreds where a small water-power offers a profitable business to a single operator with limited capital, and where the best method of utilizing that power becomes a question of vital interest. For the benefit of this numerous class of persons we illustrate herewith a dam which offers peculiar advantages in the manner of its construction, admitting at once of a high degree of strength and very close economy in point of material. Its ability to resist the force and weight of the current is founded upon one of the simplest principles of mechanical science—that of the arch, which is employed in so many forms in the builder's art where a heavy load is to be sustained or a powerful strain endured. It is hardly possible to conceive of a pressure, except it were an upheaval from below which should not occur from any other cause than an earthquake, by which a dam built in the manner here illustrated could be forced from its position. We base this statement, of course, on the supposition that due care is exercised in the construction of every part, and especially, as will be hereafter indicated, that the crib at each end of the dam is solidly built and firmly imbedded in the bank.

Our engraving shows the dam as if cut in two in the middle of the stream, the other halt being exactly similar in construction, subject to such modifications as the shape of the bank may require.

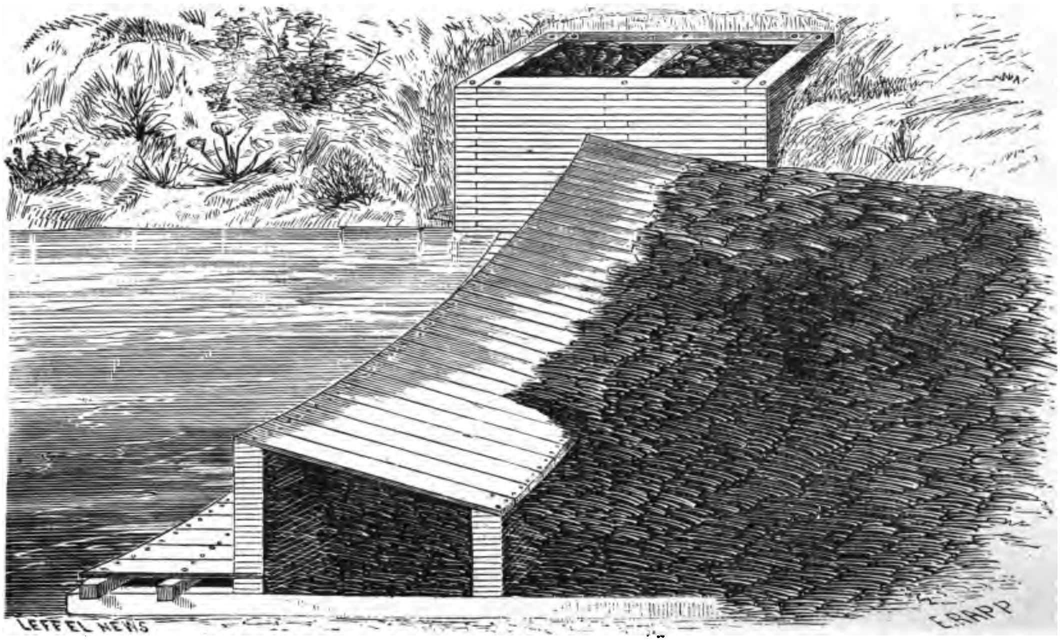
Upon a rock bottom no foundation sills are needed; but on a soft bottom, these must be first laid, lengthwise of the stream, and consisting of logs 10 or 12 inches in diameter, with a flat face hewn on the upper side, reducing the vertical thickness to about 8 inches. The length of these logs will depend upon the extent of apron it is intended the dam shall have. Upon a mud bottom a twelve-foot apron will be sufficient; but upon quicksands an apron thirty or forty feet long will be required to prevent washing out under the front of the dam; and in this case, adding the apron and dam together, the logs should be about

sixty feet long, while with a twelve-foot apron logs thirty or forty feet long will be sufficient. They may be laid about two feet apart on a mud bottom, but upon a sandy bed should be placed close together, the two edges being straightened so as to admit of a snug contact. If laid in this manner on a mud or stony bottom, the apron, consisting of the ends of the logs projecting from beneath the front wall of the dam, will not require to be planked; but on a sandy bed, or in case the two-feet spaces are left between the logs, the apron must be planked as shown in the cut. The foundation sill is represented in the engraving as a timber accurately squared on all four sides; but this is not necessary, as a log with the flat upper face and two straight edges will answer every purpose.

The foundation having been completed, reaching from bank to bank, the walls of the dam, the two cribs and the apron are next to be constructed. The cribs and the dam are carried up together, and the planks of which the apron is composed (the cross-sills having been previously gained upon the foundation logs and firmly pinned), are extended into the front wall of the dam as will be seen in the cut. The sills for the apron may consist of timbers six inches square, and 2½ or 3-inch hard wood planks, strongly pinned to the sills, should be used for the covering at this point. For the walls of the dam and cribs, two-inch planks are sufficient; and every other plank in the wall of the dam should pass through that of the crib, thus constituting a part of the partition wall inside. The effect of this arrangement will be that half the planks in the dam will pass into the crib, and the other half will abut against it, so that it will hold firmly against the pressure brought to bear on it, from whatever direction it may come, and no separation of the dam from the crib can in reasonable possibility occur.

Before carrying up the walls, however, it is necessary to fix the direction of the arch or up-stream curve of the dam. For this purpose a general rule may be given, as follows: Supposing the width of the stream between the two cribs to be 100 feet, take a rope of that length and attach it to a stake in the middle of the stream far enough below the dam so that the up-stream end of the rope will just reach the middle of the inner wall of either crib, or the point where the dam is to rest against the crib; then, keeping the rope tightly stretched and carrying the up-stream end across from one crib to the other, it will describe the curve which the dam should follow. In other words, the front wall of the dam should constitute the arc of a circle of which the radius is the distance in a straight line between the cribs. This is, as we have said, a good general rule for the purpose, though it is subject to variation according to the shape of the banks, depth and force of the current, and other circumstances. Against a very powerful current, or if the banks are low and not very substantial, the dam should have a greater curve up-stream than if the current is moderate, or the banks rocky and firm.

The direction which the two walls of the dam are to take having thus been ascertained—the lower or up-stream tier of planks being parallel



A PLANK CRIB DAM.

with the higher tier—the planks are laid up so as to form a solid barrier across the stream, breaking joints, and each plank strongly pinned to those below it, and neatly fitted and jointed where they meet, and also where they come in contact with the crib. The hight of the front wall, in such a dam as that here illustrated, is about ten feet, that of the rear wall a little over five feet, and the distance between their centers ten to twelve feet. The cribs, composed of two-inch planks, laid up in the same manner, have a partition dividing them in the middle as shown in the cut; and the front wall of the dam should abut against and connect with the end of this partition, as already described. The hight of the cribs will be determined by the the shape of the banks, in which they should be imbedded as firmly as possible, being surrounded on three sides by solid ground or substantial filling of gravel or stones.

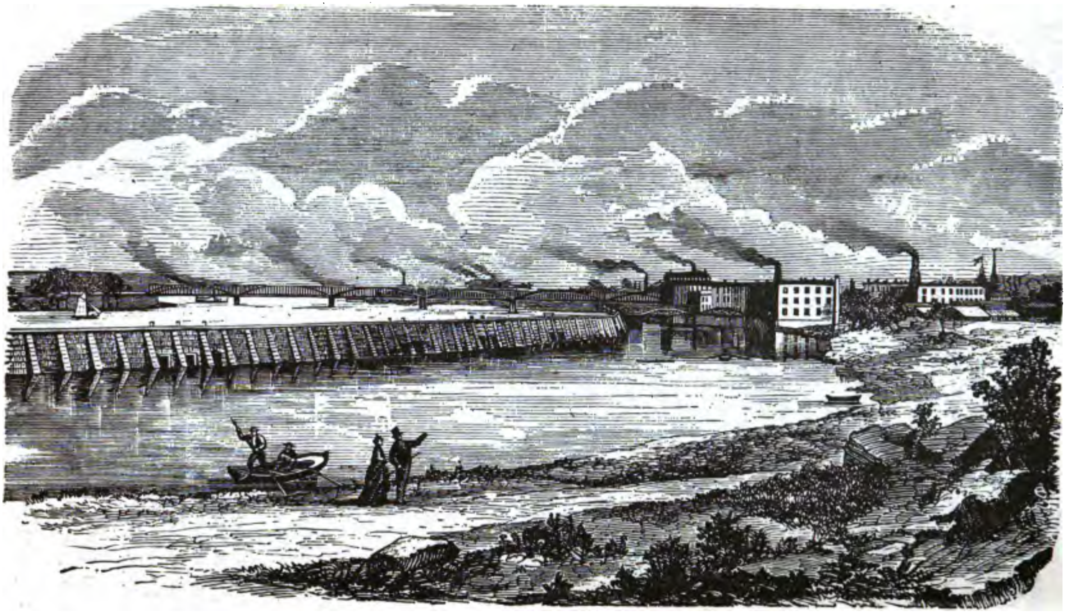
For the covering of the dam three-inch planks may be employed, placed snugly together and solidly pinned to the two walls of plank on which they rest.

The dam is filled between the walls, back of the rear wall and over the lower part of the covering, with earth, gravel or coarse stone; and the same material may be used to fill the two apartments of each crib.

It will be manifest upon a moment's consideration, that the pressure of the water upon this dam will be like that of the superstructure of a building upon the arch on which it rests, tending to spread the arch outward. As it is held in this case by the crib at either end against which it abuts, it cannot spread out except by absolutely crushing the cribs or pushing them into the bank, neither of which events can happen if the cribs are properly filled and backed up. We do not know of any arrangement comprising so small an amount of material and so simply constructed, by which a greater power of resistance is afforded.

A dam may be built on this principle with still less material, by erecting but a single wall and letting the covering extend back from the top of this wall to the up-stream end of the dam; or the covering itself may be dispensed with, and the gravel and stone simply filled in against the single front wall, constructed as already described. This is the simplest and cheapest form in which the dam can be built. The cribs must be strongly put up, whatever may be the plan of the dam, as the pressure which would tend to spread the dam must in any case be resisted at this point.

A dam of this description may have three walls instead of two, in case it is desired to carry it to a greater hight than that here indicated. Another and more radical change of the plan is to exactly reverse the dam, making what is here the up-stream the down-stream side, the high wall being farthest up-stream and the lower walls below it. In this case the covering extends from the highest or rear wall to the foot of the dam down-stream, making it, in effect, a long inclined apron. For this style of dam, a fill is made on the up-stream side of the high wall reaching about two-thirds the hight of the wall, and extending up-stream far enough to cover the upper ends of the foundation logs. These logs project down stream a short distance beyond the foot of the dam, and



THE MOLINE DAM.

may be planked at this point, unless they are laid close together, in which case the planking will not be necessary.

The pins used in securing the planks should be $\frac{3}{4}$ of an inch square in a $\frac{3}{4}$-inch hole, where soft wood is used; but in hard wood the pin should be somewhat smaller.

For the covering of the dam, instead of using three-inch planks, a double covering may be made of two-inch planks, laid so as to break joints; or in place of either, what would be called among backwoodsmen a "puncheon floor" may be constructed; a log being sawed or split for this purpose into strips or slabs four or five inches thick, and these pieces scotched at the ends to an even thickness, where they are pinned to the two walls of the dam.

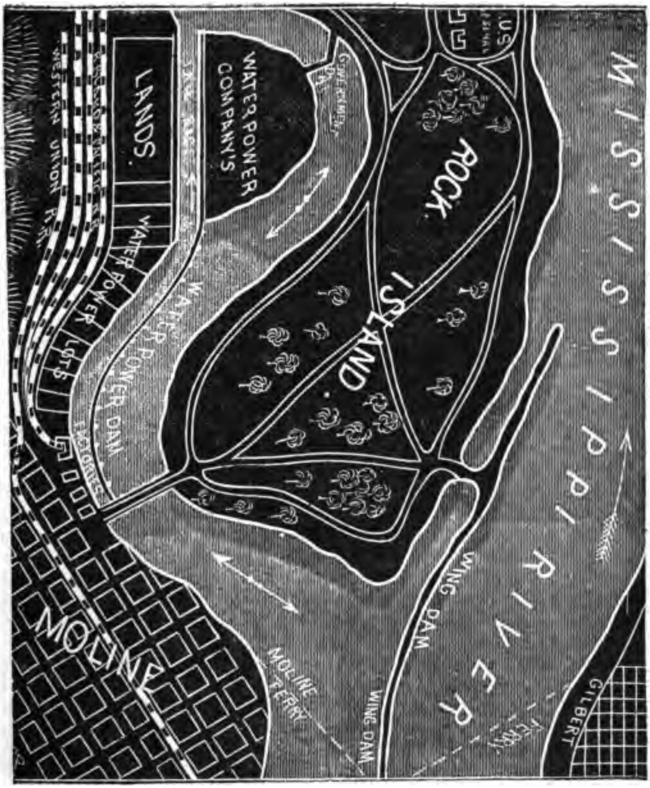
One of the main advantages of this dam is the ease and rapidity with which it may be put up. A hundred men, if necessary, may be employed upon it at once and the work thus carried forward at any speed which the circumstances may render desirable.

CHAPTER XI.

THE MOLINE DAM.

One of the most extensive and liberally developed water-powers in the United States is that located at the town of Moline, Ill., situated on the east bank of the Mississippi River, immediately opposite the head of the island known as Rock Island, situated about 300 miles above St. Louis and midway between that city and St. Paul. The water-power lies between the Illinois shore and the island, and is near the foot of the upper rapids of the Mississippi—a succession of rapids or falls, extending over twenty miles of the river channel, and having an aggregate decline of eighteen feet in that distance. The effective head is secured by extending a wing wall from the point of the island, nearly three thousand feet in length, which, with the island and main shores, gives a water surface of several hundred acres. With this length of wall, a permanent head of seven feet is obtained, and the body of available water is so large that this gauge can scarcely be perceptibly decreased.

An effort was made as early as the year 1843 to develop the power so manifestly and abundantly available at this point; and a rude dam was thrown across the channel and a mill operated with the force thus obtained. Although of slight importance in itself, this enterprise was the foundation of the immense development of manufacturing resources which has since been witnessed, inasmuch as it served to attract a considerable number of settlers to the locality, and in fact gave to the town the name it has since borne—the word Moline being a corruption of the French term MOULIN, signifying a mill. Improvements were after-



MAP OF THE MOLINE WATER SUPPLY AND VICINITY.

ward made upon the power, and additional manufacturing establishments erected upon it; but the lack of sufficient capital for such expensive undertakings prevented the work from being carried on either so rapidly or on so large a scale as would have been otherwise attempted. In process of time the power passed into the hands of a company, who held title in connection with it to some two hundred acres of land bordering on and adjacent to the river.

At the close of the war the United States Government, which is proprietor of the island of Rock Island, selected it as the site of a great arsenal and armory for the manufacture and storage of war material. In order to avail itself of the Moline Water Power for running the immense amount of machinery to be used in its workshops, the government, in August, 1867, while General Grant was acting Secretary of War, entered into a contract with the Water Power Company, by which the company ceded to the government their portion of the power, the government, on the other hand, binding itself to make certain specified improvements, develop the power at its own cost, and give the company a perpetual title to one-fourth of the whole, free from rent, repairs and expense of every kind whatever. The government also contracted to rent additional power to the company, at a fixed price.

In pursuance of this contract, the necessary appropriations were made by Congress, and the work was begun forthwith. The old dam was torn out, the reservoir deepened, and the adjoining banks of the island raised and rip-rapped with rock. A wall of the heaviest Joliet rock was built longitudinally with the channel of the river, 2,400 feet in length, twenty feet in hight, eight feet wide at the base and sloping to four feet at top, with supporting buttresses of three feet at intervals of ten feet. This wall is a massive piece of masonry, set in the bed rock of the river, beyond the power of flood or ice ever to disturb it. The adjoining bank, as already stated, was heavily rip-rapped to secure it against washing; and all the work done by the government was of the most substantial character. Meanwhile the Water Power Company deepened the channel for carrying off the tail water and put in a bulk-head; and the manufacturers located on the Power set their wheels. The remaining work was an addition of 1,400 feet to the longitudinal wall, and the excavation of a canal across a projecting point of land 2,100 feet in length, to carry off the tail water and discharge it below the Power.

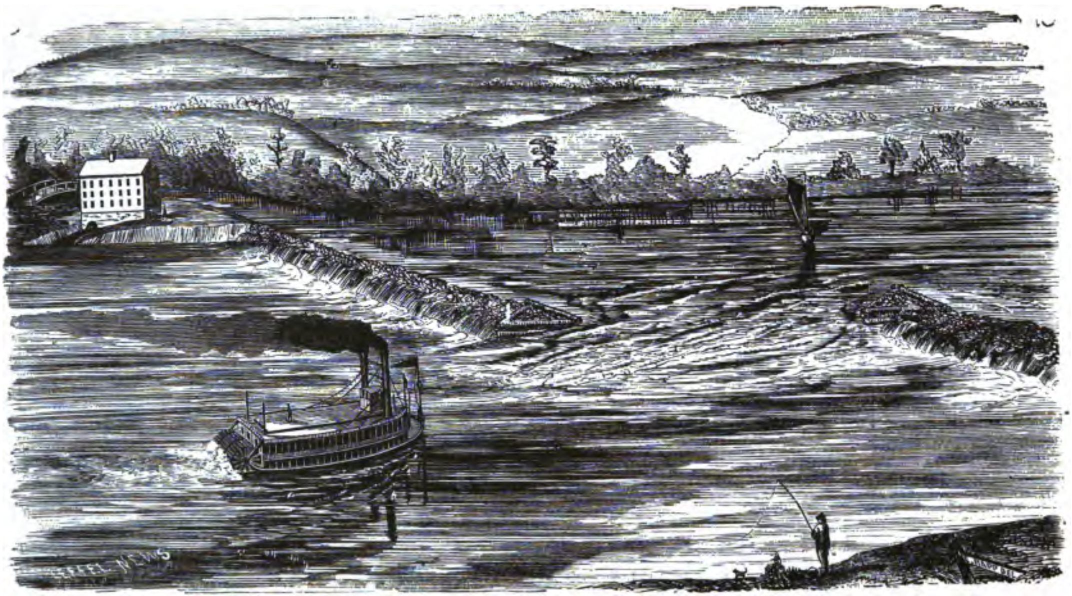
In the first of the two engravings herewith presented, a general view is given of the dam and water power, and in the second a full and accurate map of the same, showing the Water Power Dam, the Government Dam, the wing dam, the town of Moline, the factories, water-power lots and lines of railway, Rock Island, the Mississippi River and both its banks. By the aid of these illustrations the construction of this immense work will be clearly understood, and some idea of its magnitude will also be gained.

CHAPTER XII.

A BOULDER WING DAM.

There are numerous localities, especially in the Western States, where a water-power of considerable value may be obtained by diverting a portion of the current of a stream of too great width and volume for the erection of an ordinary dam, directing the water into the race, and making the latter of considerable length so that a fall of several feet may be produced, with an abundant and unfailing supply of water. In such cases, it has been found in practice a very expedient course to build what is called a Wing Dam, an example of which is presented in the accompanying engraving. This consists of a dam in two distinct sections, one on each side of the stream, and one section considerably farther down stream than the other. The obvious purpose of this arrangement is to throw the current, by means of the upper wing of the dam, to the opposite side of the stream, where it encounters the other wing and a part of it passes into the race, the remainder escaping around the inner end of this portion of the dam. This, of course, does not constitute an economical appropriation of the full power of the water contained in the stream, and is only adapted to cases in which there is a plentiful supply of water. Another and very important use which this description of dam is made to serve is that of forming a channel for navigation in streams which in their natural state are too shallow. An instance of this kind may be observed on the Mississippi river in the vicinity of Keokuk, Iowa, where a rapid occurs in the stream for a considerable distance, and the depth of water, without some artificial concentration, would be insufficient to allow a boat of any considerable draft to pass. A series of wing dams or breakwaters has therefore been constructed at this point, alternating from bank to bank, and keeping the water in a comparatively narrow channel, of such depth as to admit of navigation.

A wing dam is particularly adapted, or rather is most conveniently built, across a stream having a gravel or stone bottom, as its construction renders it peculiarly liable to be undermined at the inner end of each wing. The distance to which the wings extend into the stream will be determined by the width and depth of the river, the strength of the current, and other attendant circumstances. In very wide and shallow streams where the current is not powerful the wings may lap beyond the point at which they would meet if started at directly opposite points; but in a deeper and swifter current this would not be advisable, as the water would be very apt to undermine the exposed ends or abutments of the wings. For the same reason it is a work of somewhat difficult nature to build a dam of this kind upon a soft bottom, especially where quicksands occur; the great obstacle being the tendency of the current to wash out beneath the foundation of the cribs. This can only be obviated by driving down piles very thickly and to a



A BOULDER WING DAM.

considerable depth, and attaching the timbers of the dam to them. The extent to which the precautions of this nature must be carried will depend upon the character of the river bed and all the other conditions above alluded to, which must be carefully considered and estimated in order that the structure may be made capable of resisting the attacks which will be made upon it.

On a solid bottom, this description of dam may be built in the style and of the material of any of those which have been illustrated in preceding chapters, either logs, planks, crib-work, gravel or boulders being used, as may be found most economical or convenient. In our illustration a dam is shown, constructed of boulders with a crib abutment at the inner end of each wing. The process of building such a dam is very simple, and requires but brief explanation. The cribs are first to be laid, as great difficulty would be experienced in their construction if deferred until the other portions were finished, on account of the current which would then have been created by the confinement of the stream. In building the cribs, logs ten or twelve inches in diameter and about twenty feet in length should be used, notched upon each other and firmly pinned together; and in some cases, even on a moderately firm bottom, it may be well to drive down piles at the corners of the cribs and pin the logs to them as strongly as possible. Upon a rock bottom the foundation logs should be fastened down by means of anchor-bolts. The cribs are of triangular form, the point being up-stream; and they are to be filled with coarse stone or gravel, or any material which is not liable to be washed out. The boulders for the remaining part of each wing are then thrown in, a broad base being given to the dam to secure the requisite stability. The hight of the dam and cribs should be such as to bring them a few feet above low water mark. In time of flood, the water will of course pour over the whole structure.

The construction of the race does not differ from that employed in connection with an ordinary dam, except that to obtain the necessary fall it requires to be carried an unusually long distance below the point at which the water enters it. In some localities the race is made a mile or more in length, the descent being so gradual that an effective head cannot otherwise be obtained. But notwithstanding the apparent wastefulness of this method of utilizing the power of a stream, it is often very profitably employed, and is indeed in many cases the only practicable means of turning to useful account the resources offered by a water course of great width and very gradual fall, or upon which, owing to its interference with navigation, a dam cannot be constructed.

The length of race represented in our illustration is less than will usually be required with a dam of this description, the fall here shown in the stream being comparatively rapid.

CHAPTER XIII.

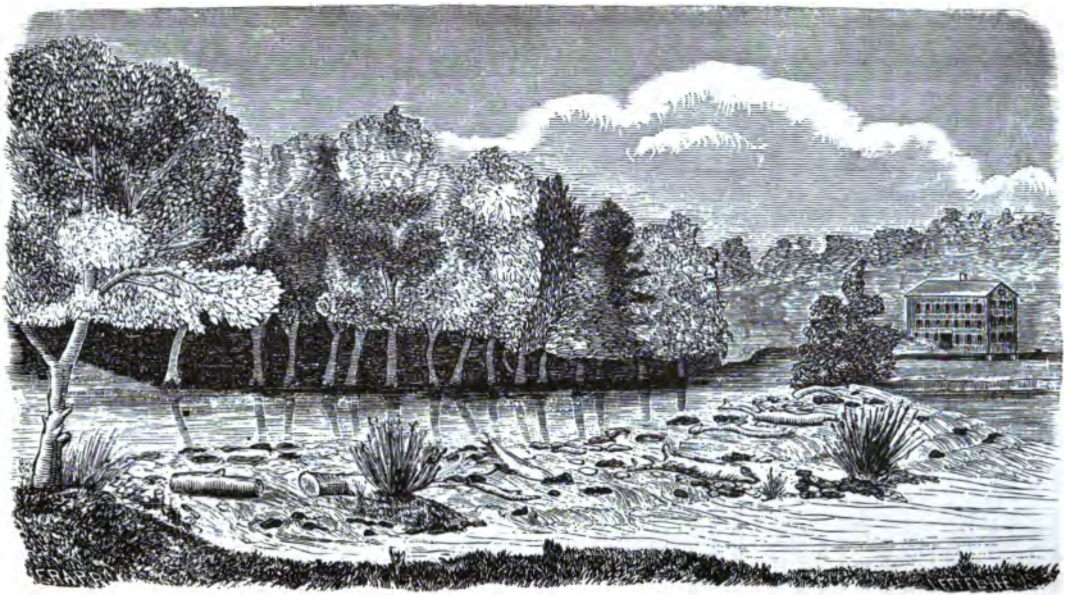
A BRUSH, STONE AND GRAVEL DAM.

It frequently happens that a dam is to be built in a locality where neither timber nor rock is extremely abundant, although both are to be had in moderate quantities without excessive cost; and where the bed of the stream is such that any one of a dozen different methods may be followed in the erection of the dam, neither possessing any striking advantages over the rest. In such a case as this it is a matter of economy to the mill-owner to use all the different resources at his command without any disproportionate tax upon either; and by availing himself of all the favorable conditions presented, he can generally make a strong and reliable dam without employing, to any great extent, the skilled labor of the carpenter. A dam of this composite character, including logs, brush, stone, gravel, sand, loam, and even clay in its materials, and depending upon its shape rather than on any peculiarity of construction for the necessary durability, can in many places be made more cheaply than any which we have yet described.

The engraving herewith presented gives a view, taken from nature, of a dam of the kind above referred to, the locality being on Mad River, in Clark County, Ohio, and the owners of the power Messrs. Snyder & Bro., proprietors of a flouring-mill and several other manufacturing establishments. The bottom of the stream here shown is a mixture of mud, sand and gravel, with a low bank of black soil. In constructing the dam, the first step taken was to throw in large quantities of brush, which was piled up until it reached, as it lay in its loose state, a height of ten feet or more. Boulders and coarse stone were then thrown in, crushing down the brush, and toward the top of the dam finer rock and gravel were put in. The brush and stones, being thus piled and mixed together, had the effect to hold each other in place; and it should be observed that the brush was of all sizes, trees and saplings, some of them forty feet in length, being laid in with the butts down stream.

In topping off the dam, the rocks and gravel were thrown on so as to form a natural slope on the face or down-stream side. The dam was so built as to form a curve, arching up stream, so as to throw the water passing over it toward the center and thus protect the banks from washing. The length of the dam here illustrated is about 100 yards and the height about four feet, the stream being of considerable width and comparatively shallow. The crest of the dam is of course irregularly proportioned, but it has an average breadth of about six feet.

Especial care must be taken in putting in the "filling" of a dam of this description—for which purpose gravel, sand and loam are used—to close up thoroughly all the spaces and apertures between the rocks



BRUSH, STONE AND GRAVEL DAM.

and among the brush and logs. If these are not completely filled, the water may find its way into the interior of the dam and it will be almost impossible to repair the mischief when discovered. If clay is used at all in filling, it must be in small quantity, and thoroughly mixed with the other materials, as it is the most unreliable of them all in resisting the inroads of the current.

The base of a dam of this kind requires to be of considerable extent in order that it may be perfectly durable. A width of twenty-five feet from the foot of the upper to that of the lower slope will in ordinary cases be sufficient. It will be seen by the engraving that a dam of this sort becomes in process of time a permanent barrier to the current, apparently more the work of nature than of art, but none the less effectual in rendering available the power of the stream.

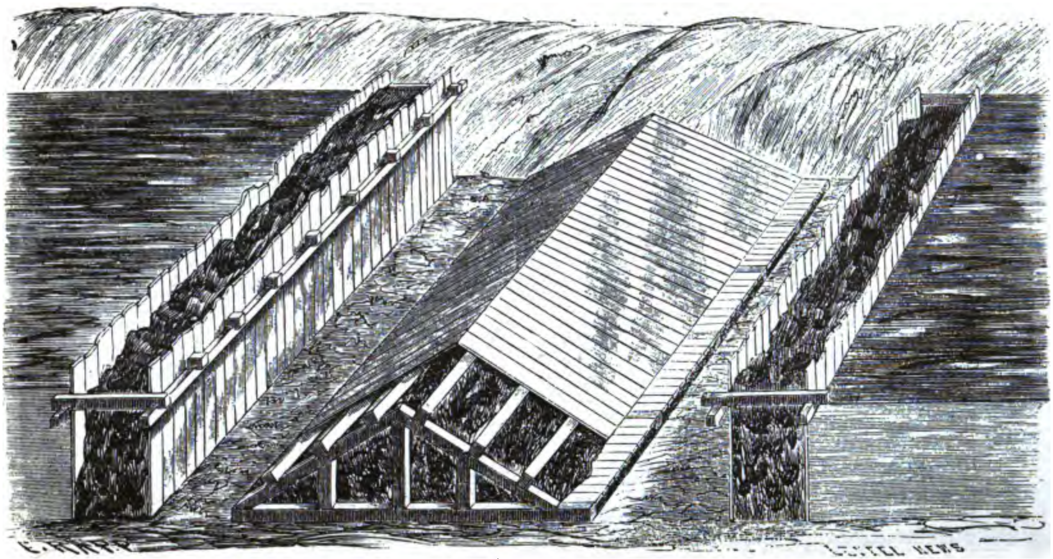
Nearly all the dams on Mad River are of the same general description as the one here represented, and have proved very durable, having stood the test of many years' use, and numerous floods of great violence. The locality shown in our sketch possesses peculiar historic interest, being within a few hundred yards of the birth-place of the celebrated Indian warrior, Tecumseh, the tragical end of whose career has formed the theme of much vivid description and supplied one of the most familiar illustrations of the school geographies of the last generation.

CHAPTER XIV.

CONSTRUCTION OF A DAM BETWEEN COFFERS.

The necessity of a coffer dam to protect the permanent dam while in process of construction is sufficiently understood by most persons; but the manner in which the work is undertaken and carried through is not so fully known.

The coffer dam here represented is of the kind adapted to streams having a mud, clay or sandy bottom into which the piling can be driven. Where the stream has a rock bottom a different mode of procedure is called for, of which we have only space in this chapter to say that it requires in the first place the sinking of cribs filled with stone, at suitable distances apart, against which crib sills are laid and planks thrust down vertically on the outer side of the sills, against which they will be held by the pressure of the water; or if the cribs are very close to each other, the planks may be put down horizontally, the water holding them against the cribs. For the coffer illustrated in our engraving, the first step is to drive down the piling, for which purpose planks should be used eight or ten inches in width and two or three inches thick, according to the depth and resulting pressure of water. For each coffer—the one above and the other below the point where the dam is to be built—two rows of piling are driven down, from



CONSTRUCTION OF DAM BETWEEN COFFERS.

two to four feet apart, and to a sufficient depth to give them strength and firmness, the requisite depth depending on the solidity of the bottom. Particular care must be taken in driving down the piling to keep the planks as close together as possible, so that any liability to leakage will be avoided. The space between the two rows of piling is filled in with any convenient material which will not wash out. Clay will answer the purpose, but soil or loam containing but little clay is to be preferred, and is still better if mixed with hay, straw or long manure next to the sides of the planks. The liability of clay to wash out has been alluded to in previous chapters, and where the other materials mentioned can be obtained it is advisable to use them. Previous to the filling, however, binders must be put in as shown in the cut, for which purpose four or six inch scantling may be used. The cross pieces, of the same material, are pinned to the binders and serve to hold the two rows of piling against the tendency of the filling to spread them apart.

The distance between the upper and lower coffer will be in ordinary cases from 50 to 200 feet, according to the width it is intended to give to the dam. It is important that plenty of room should be left between the coffer and the dam to admit of working and hauling in material from the shore side. If the coffer, owing to very strong pressure or some accidental imperfection in its construction, is found liable to cave in, it may be braced on the inner side, the props extending from just beneath the binder to the ground; or the same object may be accomplished by placing timbers across the entire width between the coffers (if the distance be not too great) above the top of the dam.

The coffers having been carried to the middle of the stream, they are to be connected at the end by a structure of the same kind extending from one coffer to the other, and thus leaving the current of the river to pass on the unobstructed side of the stream. The construction of this end-coffer, which has its direction parallel with the stream, is in all essential respects the same as that of the upper and lower side-coffers. The next step, the entire coffer for this half of the dam having been completed, is to pump the water from the inside of the enclosure, which must be done with a steam engine and pump of suitable capacity. The first half of the dam is then put up to its proper height. This having been done, an additional end-coffer is put in, within the enclosure, ten or fifteen feet from the mid-stream end of the dam, and parallel with the stream and the end-coffer previously erected. This extra coffer extends between and connects the two main upper and lower coffers, and unites at its middle with the dam, its connections with which must be perfectly tight. The upper and lower coffers, from the shore to the cross-coffer last constructed, are now torn out, and similar coffers are built from the other side of the stream in the manner already described, connecting with the portions of the first coffers which remain standing. The end-coffer first built is now taken out, which leaves the enclosure on this side complete, with the dam projecting into it ten or fifteen feet. The water is now

pumped out of the new coffer and the remaining half of the dam is then built.

The second coffer must be made somewhat higher than the first, as the water, which is changed to the side of the stream from which it was turned by the first coffer, has now to pass over the dam, and will consequently rise to a greater height on the up-stream side. In the cut, a comparatively sluggish stream is shown, the water being at nearly the same height above and below the coffer; but in a rapid stream, the water will be lower below the coffer, and the down-stream side of the coffer need not therefore be made so high as the up-stream side.

The dam having been completed in every respect, all the coffers which remain standing may either be taken out or left standing, as desired, and the work is done.

In our illustration, a frame dam is shown in process of construction between the coffers; but it is of course a matter depending upon the choice of the builder and the circumstances of the case what kind of a dam shall be erected. As the frame dam which we have chosen to illustrate in this instance is of a somewhat different character from those represented in previous chapters, we will briefly describe its mode of construction. The sills of this dam are thirty feet in length and 12 inches square. The bents, each one of which is composed of a sill, three upright timbers and two rafters, are placed at a distance of 10 or 12 feet apart, and all the timber used in them should be of nearly the same width and thickness as the sills. The rafters and uprights are strongly pinned to each other and to the sills. The ribs or stringers of the frame are 12 by 8 or 10 inches, and are bolted to the rafters. The planks of which the covering of the dam is composed are 2 or 3 inches in thickness and from 10 to 16 inches wide, and are spiked or pinned to the ribs. The joints of the planking should be made very close to prevent the dam from leaking; or what is still better, the planking may be made double, the upper course breaking joints with the lower; in which case the planks need not be so thick. In the cut, a narrow apron is shown on the down-stream side of the dam, the planks of which extend inward under the covering, and are spiked or pinned to sills beneath them running lengthwise of the dam. This apron may be made much wider if the flow of water and the nature of the stream render it desirable. The height of the dam in our illustration is about ten feet. For the filling, gravel, small stones or boulders, mixed with soil, should be used. Upon a tolerably firm bottom this dam will be found very safe and durable, its broad base and the manner in which the water strikes and escapes from it being such as to give it a high degree of resisting power.

In taking down the coffers, it should be here remarked, the filling which has been used in them may be thrown on the up-stream side of the dam, where it will serve a very useful purpose in preventing the entrance of water and undermining of the structure.

CHAPTER XV.

STONE DAM NEAR FRANKFORT, KENTUCKY.

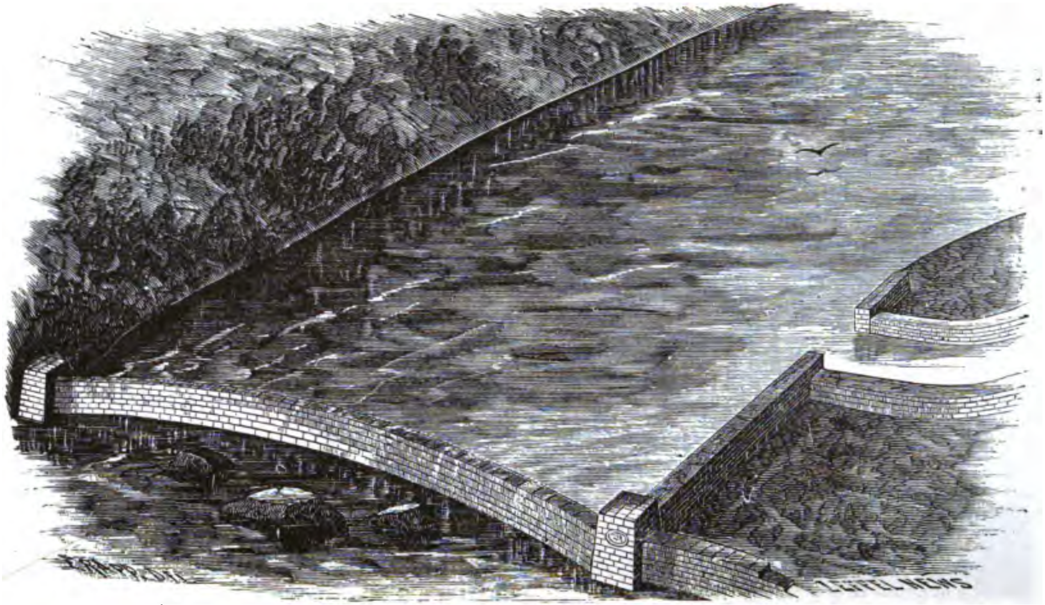
The science of dam-building is a comprehensive one, the examples embraced in it ranging from the rudest and cheapest barrier which can be built of earth and stones, for a small mill, upon a shallow stream, up to the most extensive and costly structures, such as the Ousatonic and Moline dams illustrated in previous chapters. The engraving herewith presented gives a view of a dam which may be considered as belonging to the last mentioned class, inasmuch as it could be profitably built only where a large business is to be done and an ample amount of capital is invested. The massive and substantial character of this dam will strike the reader at a glance; and it has, in fact, quite an imposing architectural effect with the two towers at its extremities and the heavy masonry extending from and connecting them.

The stream on which this dam is built has a rock bottom, which is leveled down to receive the foundation stones. The stones in the main portion of the dam and in the towers are each about two feet thick, four or five feet wide, and from six to eight feet long. They are laid lengthwise with the dam, and are cut wedging or beveled at the ends so as to fit snugly to each other and form in a solid manner the curve of the dam, in the same way that the stones of an arch are shaped to correspond with the form of the structure. They are laid in hydraulic cement, or "water lime," the nature and use of which substance, the peculiar treatment demanded for stone-work thus put up, and other details of this part of the work, belong to the special province of the stone-mason and will be sufficiently understood by a competent workman at that trade.

The face of the dam consists of one tier of stones of the size and built up in the manner above described, and the back or up-stream side is composed of loose flat stones laid up without much regularity, the work being finished by filling with earth and small stones, making a tolerably gradual slope on the up-stream side and giving the dam a wide and substantial base. The face of the dam, composed of the solid tier of masonry, inclines slightly up-stream, varying but a foot or two from a perpendicular.

The length of the dam here shown is about 300 feet between the towers. Its width at the base is 8 feet and at the top 5 feet, and its height about 12 feet. The towers are each 17 feet high, 18 feet square at the base, and 12 feet square at the top. The number of courses of stone in the main dam is six, the stones being, as already stated, two feet thick.

From the tower at the right of the picture a wing or continuation of the dam runs out, keeping the same general direction as the dam itself, its purpose being to keep the earth from washing out, the bank being common soil and very low on this side of the stream. On the other



STONE DAM NEAR FRANKFORT, KENTUCKY.

side the bank is of sufficient height to require no protection of this kind. The dimensions of the wing wall are less than those of the main dam, as it has much less pressure to resist. From the same tower with which the wing wall connects, a side wall of somewhat greater width and height extends up the stream, along the bank to the entrance of the race, protecting the bank from being overflowed or worn away by the stream. A similar wall also extends a short distance above the race, and both sides of the race are in like manner strengthened against the action of the water, their walls being somewhat lower than those along the banks of the stream. At the entrance of the race are placed head-gates, which are not represented in our engraving.

A tablet on the face of one of the towers bears the name of the owner of the dam, date of construction, etc.

Our illustration gives a view of the dam by which the power is furnished for the extensive flouring mill of Mr. Geo. B. Macklin, four miles from the city of Frankfort, Kentucky. The course of the stream at this point is such (making what may be called a "horse-shoe" bend) that by running the race from 200 to 300 yards a fall of 21 feet is obtained. The firm of James Leffel & Co. have put in three of their improved Double Turbine wheels in this mill, from which fact an idea may be formed of the amount of business it is designed to maintain, and which fully justifies the thorough and durable manner in which the dam has been constructed. The dam was completed about eleven years since, and is one of the most substantial structures of the kind to be found in the West or South.

CHAPTER XVI.

PILE AND BOULDER DAMS.

A point of vital importance in the construction of a dam is to provide against the effects of the overflow, which has a constant tendency to undermine the foundation of the dam by gradually washing out or wearing away the bed of the stream at the point where it strikes. This is in fact one of the chief difficulties to be taken into account in building a dam, and it is at this point, perhaps, as frequently as any other which can be named, that they prove to be defective. The working of the water in the manner described is often so gradual and insidious that its effect is unobserved until made apparent by the giving way of the foundation at one or more points, and this very probably at a season of high water, when even an attempt to repair the mischief is scarcely possible and is apt, if made, to prove ineffectual. The location of the breach, moreover, being at the very base of the dam, where the weight of the structure and the pressure of the water bearing upon it is chiefly felt, renders the task of making good a defect of this kind after it has

FIG.I.

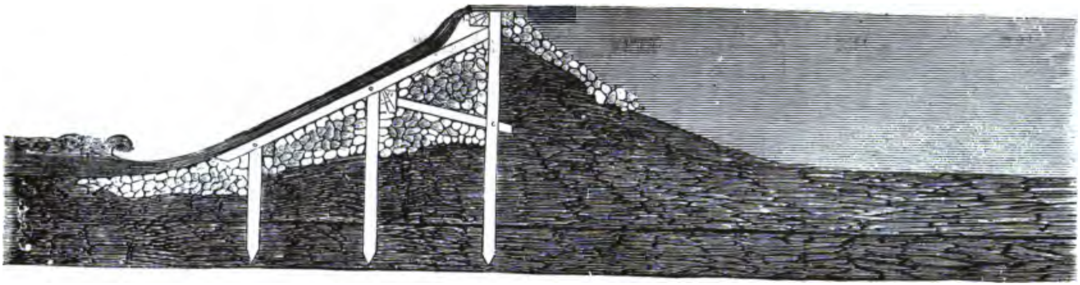
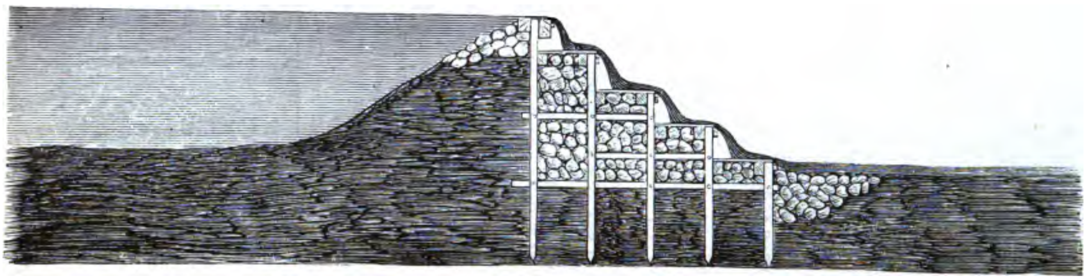


FIG 2



PILE AND BOULDER DAMS.

thus betrayed itself an exceedingly arduous one. In many instances it has been found impossible to perform the work successfully, and the loss and entire rebuilding of the dam has proved the necessary consequence of the neglect to make it in the first place secure against this particular danger. In this matter, as in a thousand others, experience has repeatedly shown that an ounce of prevention is worth a pound of cure. A due regard beforehand for the known conditions of the case, and the well understood action of water in flowing over a dam, will save many hundreds of dollars in subsequent repairs and rebuilding, as well as in the incidental losses which attend a breakdown of this kind.

The methods of construction adopted to prevent this destructive action of the water are various, and some of them have already been illustrated in this volume. In some cases the horizontal apron projecting from the foot of the dam down stream is found sufficient; while in others an apron is made forming a gradual inclined plane from the crest of the dam to a point some distance down-stream, thus permitting the water to escape in a swift current instead of a heavy perpendicular fall. This is an excellent method of breaking its force, provided the inclined plane is itself strongly constructed with a firm foundation and with no liability to leakage.

We illustrate in the engraving here presented two forms of construction for a dam by which the prevention of injury by underwash is effectually attained. A glance at either of the two figures in the cut will show that there is scarcely any possibility of the water wearing either downward in the bed of the stream or backward under the foundations. Both these methods of construction partake of the nature of the inclined plane, it being so modified in the second as to constitute a series of steps by which the force of the water is broken and it is carried in successive easy stages from the top to the bottom. The strength of the materials used and of the method in which they are employed will also be observed. In Figure 1 an open frame of timber is represented, into which are inserted large boulder stones, forming a compact mass of boulder sheeting resting on gravel, and nearly impervious to water. The timbers here used should be large, say a foot square, and firmly pinned together. The hight of the dam in Figure 1 is about eight feet, and the bents, each consisting, as shown, of the three uprights, the inclined rafter and the intermediate brace, should be placed at intervals of six or eight feet along the face of the dam. A stringer is bolted to the top of the second upright, under the rafter, as shown in the cut, and one end of the brace is let into this stringer, the other end being pinned to the highest upright. At the top of this upright, also, will be seen a heavy stringer bolted on each side in such a way as to form a level surface at the crest of the dam and protect the structure at that point. In addition to the brace shown in the engraving others may be put in in a similar manner, giving additional strength to the framework.

In Figure 2, the same principle of construction will be observed, with modifications suited to a region where timber is plentiful. This

structure is composed of piles driven at right angles with the direction of the stream and placed in rows, properly stayed and covered with planking firmly nailed to the horizontal and vertical timbers. If it is desired to have the structure perfectly water-tight, a line of sheet piling may be driven in, in the line of the dam across the whole breadth of the stream, and this being again supported by foot piles and stays at different distances, a tight and very durable dam is the result. The water falls in cascades over the series of steps, and any injurious effect on the foundations is prevented. The method in which the horizontal timbers are pinned to the uprights and the stringers bolted to the top of each upright will be readily understood by a glance at the cut. The timbers in this dam need not be so large as in Figure 1, six or eight inches square being amply sufficient. The bents in this, as in the other dam, may be put in at intervals of six or eight feet.

The construction of both these dams, aside from the framework, is very simple, and presents a safe and substantial resistance to the pressure of the water. The rip-rap of the embankment on the upper side may be carried farther, if desired, than is shown in the cut; and the proportions and extent of the layers of boulders may be varied in any direction according to the judgment of the builder and the circumstances of the case.

CHAPTER XVII.

STONE DAMS.

Whatever may be said in favor of other descriptions of dams, whether they be frame, crib, log, pile, earth, brush or iron dams, it must still be admitted that stone is on many accounts the most suitable material for a barrier against the pressure of water, and the one which will naturally be selected where the circumstances do not make it too costly, or where the object in view cannot be as effectually accomplished by more convenient methods. Stone possesses more of the qualities which are valuable in a dam than any other substance. Its weight, though it renders the work of building more arduous, is a source of strength when it is once in position, such as can hardly be given to any other material; it is subject to neither rot nor rust, and unless undermined or caved, in consequence of the weakness of some other part of the structure, it is not liable to yield to any of the ordinary forces which a dam is intended to resist. When properly guarded from the gradual inroads of the water through apertures or crevices, or in the form of underwash by which the foundations are sapped, a stone dam is an immovable bulwark and will withstand the heaviest freshets, saving in the long run, in many cases, by the avoidance of any outlay for repairs, many times the difference between its cost and that of cheaper but less reliable structures.

FIG.1

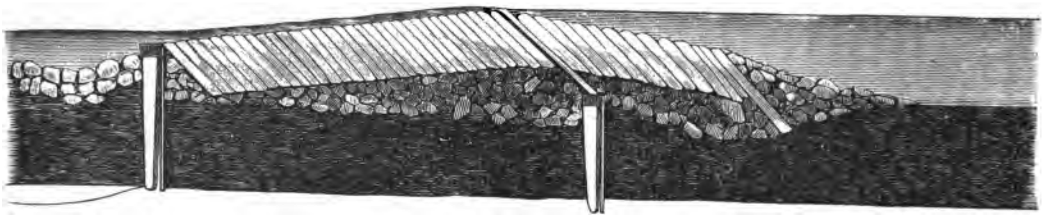
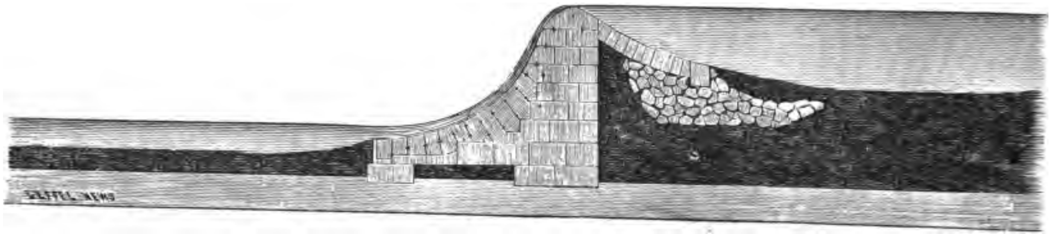


FIG.2



STONE DAMS.

We illustrate in this chapter two different forms of a stone dam, both of which have the attributes of strength and permanency, the choice between them depending on the character of the stream and the means of the builder. Figure 1 is a sectional view of a dam constructed in England by the celebrated engineer Smeaton. It has, as will be seen, a long inclined slope on each side, above and below, and the extent of base in proportion to the hight is such as to contribute immensely to the stability of the dam. At the crest of the dam and inclined downward, will be observed the ends of two courses of flag stones, which are so laid as to break joints, footed upon grooved sheet piling with bearing piles and stringer, and supported by a thick and wide layer of "rubble" or small boulders underneath the flags. Live moss is packed between the flag stones to prevent the silt being driven through. At the foot of the dam is another row of sheet piling, similarly supported, and protected by a fir plank at top from the action of the water. Over the layer of rubble is placed a row of regular stones, laid endwise and leaning, so as to be perfectly secure from derangement by floods. In the up-stream direction from the crest of the dam is also placed a layer of rubble with a tier of flat stones above it and at the up-stream end of the dam is a single course of large flags reaching from the surface to the base of the dam and held down by a filling of small stones. A dam of this kind is adapted to a stream having a soft bottom either of loam or clay; but if there is a sandy bottom the piles must be driven to such depth as will give them a firm hold, and special care must be taken to guard against underwash at the foot or down-stream extremity of the dam.

In Figure 2 is shown a dam built upon a somewhat different principle, composed of solid masonry instead of rubble and flags, and having a curved or concave apron instead of a gradual slope on the down-stream side. On the up-stream side the construction is very similar to that of the dam in Figure 1, except that stones of more regular shape are used; and in all parts of this dam reliance is placed upon heavy and compact stonework instead of piling. The water has at first a nearly perpendicular fall, but is carried away in such a manner by the curve of the apron as to entirely lose the direction which would give it an injurious effect upon the foundation. The construction of this dam throughout is so distinctly shown by the sectional view here given that it requires no further explanation.

An English writer on the subject of the construction of dams remarks that "rapid rising of the waters and sudden changes in the state of the river are too often neglected, with disastrous consequences to works of this kind, just on the eve of completion, or to the lands above the dam in consequence of flooding caused by the obstruction of the dam. In cases where this last danger is apprehended, a self-acting dam has sometimes been employed, consisting of a massive frame of planks carried across the river and attached by hinges to the crest of the dam. This plank is maintained in a vertical position in ordinary conditions of flow by balance weights attached or hung over wheels upon the wing

walls, so as to retain the maximum desirable head of water. In floods, the increased pressure of the overflowing water overcomes the balance weights and throws down the plank into a horizontal position, opening a free passage for the water."

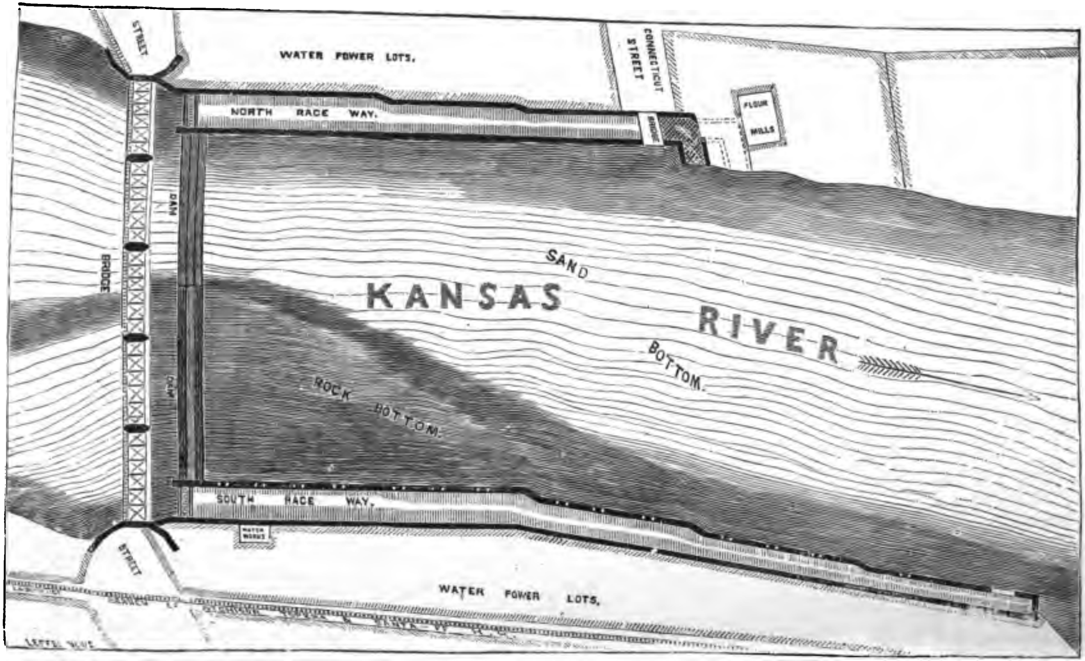
We have given, in preceding chapters of this work, a large number of plans for the construction of dams, applicable to the different situations and conditions which are likely to occur, and based upon general experience and the essential principles which are to be kept in view in an undertaking of this kind. The remaining chapters will be chiefly devoted to the illustration and description of dams which have actually been built in different localities in our country. This method, while it may give less scope for original suggestions and the discussion of useful theories bearing upon our subject, will give our readers an eminently practical view of the extent of some note-worthy enterprises of this class, and the minor details involved in their prosecution.

CHAPTER XVIII.

DAM AT LAWRENCE, KANSAS.

The engraving herewith presented is one of a series executed by our artist from the original plans of a dam across the Kansas River at Lawrence, Kansas, constituting a work of such magnitude and possessing such a degree of practical interest that we deem it worthy of minute description and illustration. The Kansas river is about five hundred miles in length, and drains upwards of fifty thousand square miles of land west of Lawrence. The minimum flow of water at Lawrence is about three hundred thousand cubic feet per minute, and has an average declension of about three and one-half feet to the mile. The water having a rapid flow, the river rises slowly in times of excessive rains, and reaches but moderate hights; the greatest rise within a period of four years being only six feet; and the water did not remain at that hight more than twelve hours.

The dam is intended to raise the water eight feet; though it has been built with a base sufficient to carry a dam ten feet in hight, whenever it may become necessary; and the river banks are sufficiently high to prevent overflow. The average width of the river is about six hundred feet. The length of the dam, including head-gates, piers and abutment, is seven hundred feet. The river bed, for three-fifths of the distance across from the south bank, is solid rock bottom; the remainder, to the opposite bank, being composed of coarse sand and gravel with occasional strata of blue clay, the first of which occurs at eight feet from the surface of low water. The dam is provided with two canals, one on each side of the river. The canal on the south side is sixty feet



DAM ACROSS THE KANSAS RIVER AT LAWRENCE, KANSAS—Fig. 1.

in width, and that on the north side fifty feet, both to be provided with suitable head and tail gates.

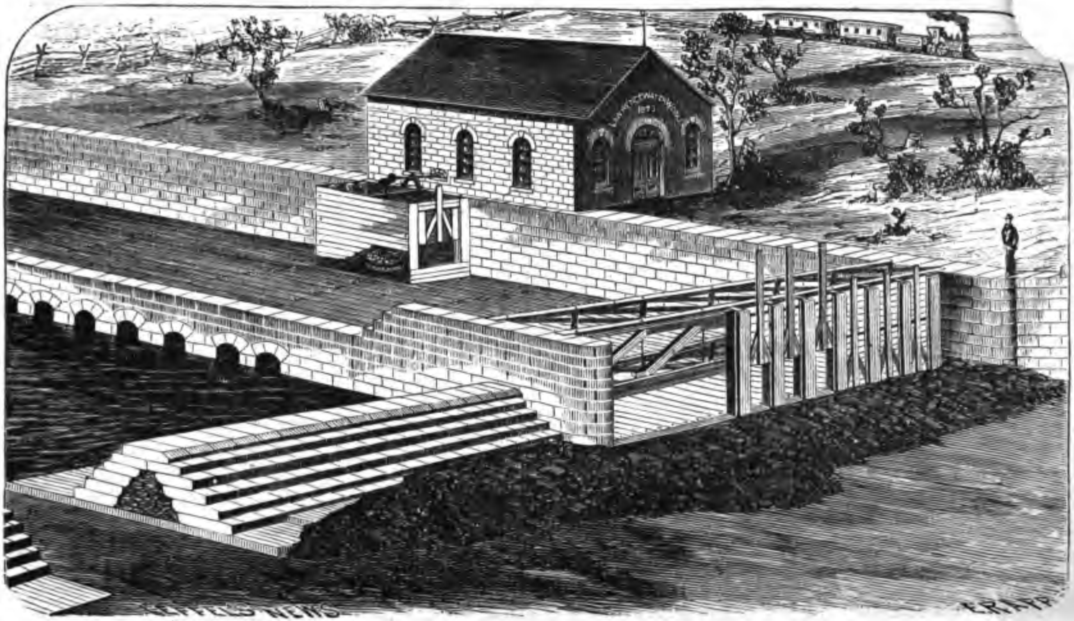
Our present illustration shows only the ground plan or map of the Lawrence dam, including also a portion of the stream and the vicinity on both sides of the river. The location and relative position of all parts of the structure are clearly shown, as are also the water-power lots, the bridge above the dam and those across the two race ways, the railroad passing the whole length of the water-power tract on the south side of the river, the location of several streets on each side, and that of the Flouring Mill on the north and the city Water Works on the south bank. The Water Works are to be operated with power obtained by means of the dam, the contract with the city stipulating that for a fixed sum it shall be entitled to use sufficient power to raise two million gallons of water one hundred and fifty feet high every twenty-four hours. This is but an insignificant fraction of the aggregate power which the dam will furnish, the total amount to be afforded according to the original plans being estimated at 2,500 horse-power; and by the increase in hight which can be made, as already stated, from 1,000 to 1,500 additional horse-power will be secured.

We reserve for our next chapter the details of construction of the dam, which will be fully illustrated, showing the thoroughness and intelligent skill with which the enterprise was conducted, and the reliable character of the structure as regards the vital qualities of strength and durability. The work was carried on by Mr. Orlando Darling, of Lawrence, a civil engineer by profession, and a man of rare energy and practical judgment. We are indebted to the courtesy of Mr. Darling for material both for this article and for our illustrations.

CHAPTER XIX.

DAM AT LAWRENCE, KANSAS.—(*Continued.*)

The river at Lawrence, as stated in our former chapter, has a rock bottom for a distance from the south bank of three-fifths of the width of the stream, the remaining two-fifths, on the north side, being chiefly sand and gravel. That portion of the dam which rests on rock bottom is 315 feet in length from the inside of the head-gate pier of the south gateway, and is to be built of cut stone of large dimensions, thoroughly cemented. We present in the accompanying engraving this portion of the dam, with the head gateway and canal on the south or Lawrence side of the river, showing also the city water-works, and the railroad in close proximity, as has already been indicated in the plan. The dam is represented as if cut in two a short distance from the head-gate pier, in order that its internal construction may be clearly seen. The north portion of the dam, resting on the sand and gravel bottom, does not



DAM ACROSS THE KANSAS RIVER, AT LAWRENCE, KANSAS.—Fig. 2.

appear in this cut, but will be fully illustrated in our next chapter.

The base of the rock dam is twenty-one feet, the whole width on top to be covered by one stone eight feet in length, with its upper corner beveled off one foot, leaving a flat surface on top of seven feet. The sides of the dam present angles of forty-five degrees with the base, and the water falls in cascades over the series of steps, any injurious effect on the foundation being thus prevented. The sides of the dam are composed of stones of not less than six feet in length and eighteen inches in thickness, laid in transversely or crosswise of the dam, the center being filled with concrete. The dam, as has already been stated, is intended to raise the water eight feet, but has sufficient base to carry a dam ten feet in hight if found desirable. The manner in which this portion of it is constructed is so clearly shown in the cut that with the aid of the brief explanation we have given it will be fully comprehended by the reader.

The head-gate way and canal on the south side, here represented, rest on solid rock, it first being excavated to below low water mark, and the water from the wheels being discharged through the arch-ways in the inside wall into the river below the dam. The floor of this canal will be hereafter described.

The stones for the masonry are all procured from a remarkable quarry of very durable stone, situated in Jefferson county, on the line of the Kansas Pacific Railway, ten miles west of Lawrence. From this quarry an unlimited amount of stone, in square blocks exactly eighteen inches in thickness and of any length and width desirable, may be procured. The two canals in connection with the dam are about one-half mile in length, and the Water Power Company owns and controls all the lands lying upon the canals, for their entire length. The water-power lots are from 150 to 450 feet in length, lying in the center of Lawrence. The railroad track on the south side of the river, which is shown in the cut, is about ten feet higher than the top of the outside or bank wall of the canal, which is eighteen feet high, above low water. The inside or river wall, below the piers, is nine feet high, being only two feet higher than the dam, and will serve as an overfall for the water in time of flood.

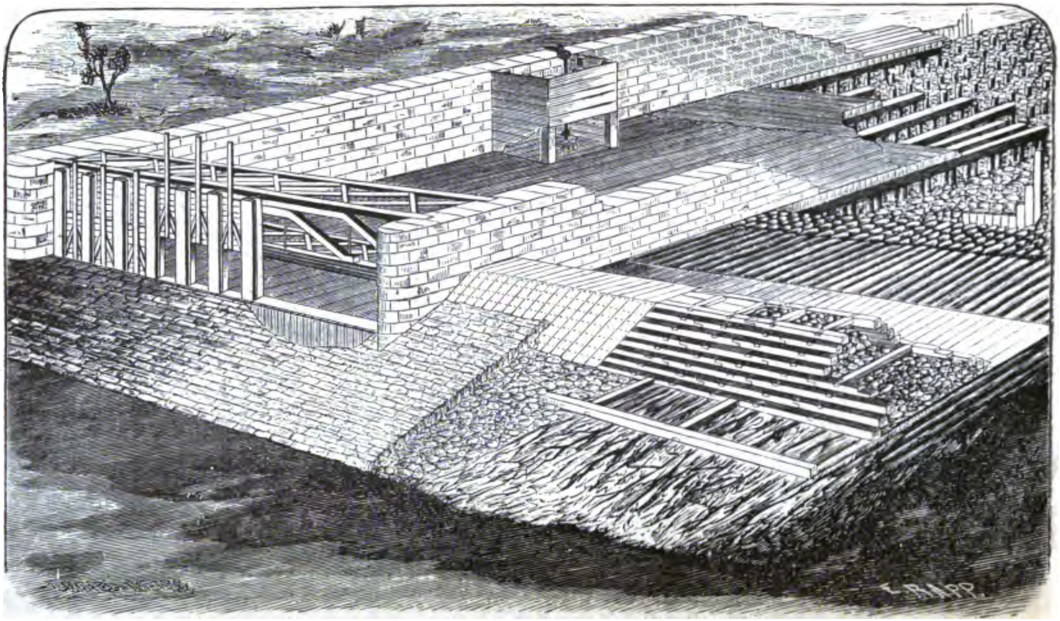
The construction of that part of the dam resting on the sand and gravel bottom will be described and illustrated in our next chapter, together with some additional particulars in reference to the canals and head-gateways. This remaining portion of the dam comprises 210 feet of the distance across the stream, inside of the head-gate piers, having but about two-thirds the length of the part built on the rock bottom; but its construction presents more difficult problems in engineering, and more interesting features as regards the selection of materials and their employment in such a manner as to secure the requisite strength and solidity, than any part of the work thus far described. A rock bottom gives a natural foothold for the superstructure of a dam which greatly simplifies the task of the builder; but upon a soft bottom his ingenuity and fertility of resource are called largely into exercise.

CHAPTER XX.

DAM AT LAWRENCE, KANSAS.—(*Continued.*)

We give in this chapter our third and concluding descriptive article and illustration of the dam at Lawrence, Kansas. In our first engraving the ground plan of the entire dam and both banks of the river were shown; in our second the position of the dam resting on rock bottom, extending from the south bank 315 feet or about three-fifths of the width of the stream, including also the canal on the south side, the head gateways and the water-works building; and in the illustration here given we represent the remaining part of the dam, resting on a bottom of sand and gravel, and extending 210 feet, from the north bank to the end of the rock bottom portion, with which it connects. The canal on the north side and the head gateways are also shown; and the construction throughout is so clearly delineated in the cut that with the aid of the following description it will be easily understood, and the reader enabled to appreciate the care and thoroughness with which the work has been conducted.

The portion of the dam here illustrated is of the kind known as a frame or crib dam, and rests on a foundation of trees and rock. The bed of the stream is first reduced to a uniform depth of about five feet for a space of eighty feet up and down the stream. This being done, a tree foundation is placed in the river, composed of trees from sixty to eighty feet in length, with the limbs entire and the tops up stream. The trees are laid as close together as possible and fastened together at each end, the trunks touching each other as they rest in the foundation, and the tops interlocked so as to form a solid mat of brush. The whole constitutes a close platform, and is sunk to the bottom with small rubble stone. Five of these courses or platforms, each constructed as above described, are laid down to complete the foundation, and each succeeding course is drawn five feet up the river, as will be seen by the appearance of the butts of the trees in the cut. As each course or platform, or part of a platform, is sunk, it is thoroughly weighted, and all interstices in the brush or between the trunks are carefully filled with rubble, so as to form a solid concrete. The frame consists of eight platforms of timber, composed of two main sills 12x14 inches, laid flatwise, halved together where the ends join, and bolted with drift bolts of inch iron. The main sills are held in place by means of cross-ties 8x8 inches; the ends of which are dovetailed into the sills. The ties are put in at intervals of eight feet, and spiked to the sills with ¾-inch drift bolts. The first platform, forming the base of the dam, is twenty-four feet wide from out to out, and is gained into the upper platform of trees so as to receive a uniform and level bearing, and each succeeding course is thoroughly secured with iron bolts to the course below, receding on each side one foot. The breasts of the dam are thus given a slope of 45 degrees, and the top is finished with a level surface eight



DAM ACROSS THE KANSAS RIVER, AT LAWRENCE, KANSAS.—Fig. 3.

feet in width. An open platform twelve feet in width is also firmly attached to the lower sill of the upper slope of the dam, which practically makes the base of the structure thirty-six feet in width. As each platform is laid and adjusted, it is carefully filled with rubble rock of large size, all interstices being packed with spawls so as to form a solid body.

The frame being completed and filled with rock as above described, the outer corners of the sills are trimmed off so as to present a bearing surface of four inches, and the whole is covered with plank 2½ inches in thickness, placed in line with the current of the stream, and firmly spiked on with six-inch boat spikes. The dam having been built and completed in sections, as each section is planked over, a protection is placed on the up-stream side, extending thirty feet up the river, having a thickness of fully four feet on the open platform, and extending at least half way to the top of the dam on the upper slope. This protection is composed of large stones, all the interstices being filled with spawls. After a row of tongued and grooved sheet piling has been driven at the lower ends of the tree foundation, a large amount of rubble rock is placed upon the lower ends of the logs and in the bed of the river below. The plan contemplates the use of 10,000 yards of rubble stone, which is quarried out of the south bank of the river, immediately below the dam.

The head gateway and canal on the north side, which are represented in the engraving, rest on ten rows of piling driven closely together, up and down the river. The piles, after being sawed off two feet below low water mark, are capped by timbers 10x16 inches, laid flatwise, upon which is laid a close floor of ten-inch timbers; and this timber floor is covered with a floor of three-inch planks, laid in line with the stream and firmly spiked down with six-inch boat-spikes. On this platform the masonry is laid, each pier resting on three rows of piling driven twenty-five feet to the bed rock. Sheet piling is driven to the clay, from the bank in front of the head-gates, and along the base of the inside pier to the lower end of the tree foundation, thence under the canal to the river bank, and along the bank outside of the round piling, to prevent any washing of the bank by the discharge of the water from the water-wheels. Sheet piling is also driven along the lower ends of the tree foundation to the intersection of the rock bottom.

The canal below the tree foundation is constructed the same as immediately below the head-gates, excepting that the sand and gravel is washed out from among the piling to a depth of about five feet, and then rip-rapped thoroughly with stone to prevent any further washing. Water-wheels may be located on either side of this canal by merely cutting a hole in the floor to receive the tube of the wheel, and the water is discharged under the canal into the channel of the river below the dam. The outside or bank walls below the piers are six feet thick at the base, battered on the outside to three feet on top, are eighteen feet high above low water, and will serve as a foundation for buildings their entire length, as power can be taken at any point along the canals. The piers in which the head-gates are placed are six feet thick, without

batter on either side, by eighteen feet in hight. The inside or river walls are six feet thick without batter; and, as already stated, are nine feet high, being only two feet higher than the dam, and thus serving in time of flood as an overfall for the water.

The head-gate piers or walls on the south side of the stream are similar in construction to those above described, except that they have a foundation of solid rock instead of resting upon piles. The floor of the south canal is also the same in general construction as that of the north canal, except as regards the foundation, the posts or piers supporting it being placed on the excavated rock bottom of the canal. The manner in which the water is discharged from the wheels has been fully illustrated, archways being provided for its escape from the south canal, while from the north canal here shown it has free passage outward both at the lower end and at the side, between the piles by which the flooring is supported.

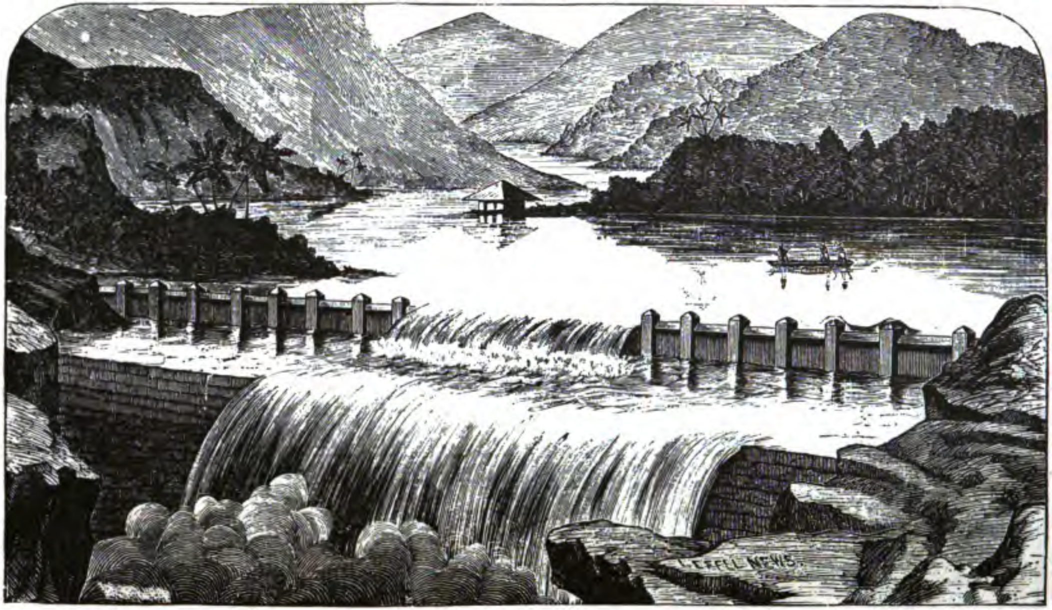
The account given of the Lawrence Dam, in the present and the two preceding chapters, was prepared in February, 1873; a fact which the reader should bear in mind in comparing the particulars here stated with the alterations or additions since made.

CHAPTER XXI.

DAM ON THE TASSOO RIVER, HINDOSTAN.

The utilization of water power for manufacturing purposes is the ordinary, in fact the almost universal object of the construction of a dam; and it has been with reference to this leading purpose that our illustrations thus far have been designed. There are, however, other useful ends for which a substantial and durable dam is sometimes requisite; and among these is the provision of the necessary supply of water for the daily use of the inhabitants of a large city. Structures of this kind and for the object indicated are to be found in various localities in our own country; but the one we have chosen for our present illustration belongs to a remote quarter of the globe and is the work of a foreign nationality; and it may possess the greater interest to many of our readers from the fact of its distance and novelty, as well as its great magnitude and the special necessity which it is to meet—that of furnishing to the people of Bombay, one of the largest cities of Hindostan, an abundant and unfailing supply of water.

The city and island of Bombay, which have nearly 800,000 inhabitants, are supplied with water from Vehar, an artificial lake in the hills of the neighboring island of Salsette. The Vehar reservoir, which was constructed by the Government of Bombay about twenty years ago, was ceded to the municipality of Bombay in 1863. It is nearly sixteen miles from Bombay Cathedral and has hitherto amply supplied the



DAM FOR THE NEW WATER SUPPLY AT BOMBAY, HINDOSTAN.

wants of the island; but the rainfall of 1871 being very small, the lake, at the end of the "monsoon," (the periodical wind which blows half the year in one direction and the other half in the opposite, and which in the Indian Ocean blows from the southwest from April to October, bringing heavy rains, after which it changes to the northeast for the rest of the year) was nearly ten feet lower than usual. Attention was thus drawn to the possibility of a short rainfall in the ensuing year, 1872, from which a deficiency of water would result, with all its consequent evils. To prevent so great a calamity it was decided by the municipality to make a new lake at Toolsi, to supplement Vehar. The valley of Toolsi is 112 feet above the top of the Vehar lake, and is divided from it by only a slight ridge of hills. Hitherto the waters flowing from the hills into the Toolsi valley have found their exit by the river Tassoo, the source of which is at the end of the valley opposite to the ridge dividing it from Vehar, whence it flows past Kennery to the sea. By damming up the source of the Tassoo, the water is impounded in the Toolsi valley, and by tunnelling through the ridge between Toolsi and Vehar, a passage is made for it into the latter lake. Of course the supply of water into Vehar from Toolsi can be controlled, and if not wanted can be kept impounded in Toolsi lake till it is required, any surplus flowing over the dam across the Tassoo, and escaping by the old route. The view given in our illustration is of the dam across the Tassoo, as it now appears, 30 feet high, with the water overflowing. This view shows but a very small portion of the intended lake, the greater part of which lies behind the low ridge stretching across the picture. It is intended to raise the dam to a height of 74 feet. The lake, which is but an auxiliary supply, has an area of 300 acres of water, containing 1,451,000,000 gallons (besides as much of the available rainfall of Toolsi as can be turned into and stored in the Vehar lake). All this water, except a few gallons, can be made, by opening the penstock in the tunnel in the ridge dividing Toolsi from Vehar, to flow into the latter lake, and thence through the main to Bombay. Vehar, when full, covers an area of about 1,400 acres, and has 2,550 acres of gathering ground, and contains 10,650,000,000 gallons, giving a daily supply of ten gallons a head, and Toolsi will increase it by 4½ gallons per head. This additional cheap water supply, which will probably last Bombay for twenty or thirty years, is expected to cost only four lacs of rupees, a sum equal to about $220,000 in United States currency.

The construction of the dam is not shown in detail in our engraving, but a sufficient portion of the structure is visible to give a very clear idea of the plan upon which it is built. The main feature of the work is the broad and solid wall of masonry, of which most of the lower or down-stream face is shown. The up-stream face of this wall is covered and protected by strong piers of timber, between which are upright planks, closely fitted and strongly secured; the top of this part of the dam being finished with horizontal stretchers extending between the piers. Midway of the stream a space is provided for the overflow of

the surplus water, which afterwards falls over the stone work of the dam into the chasm below. On the up-stream side of the timber face of the dam is a filling of stone and gravel sufficient to protect the timbers and the foundation from undermining or leakage.

These extensive and admirably constructed works were designed and carried out by Mr. Rienzi Walton, an associate member of the Institute of Civil Engineers, and the acting executive engineer of the municipality of Bombay.

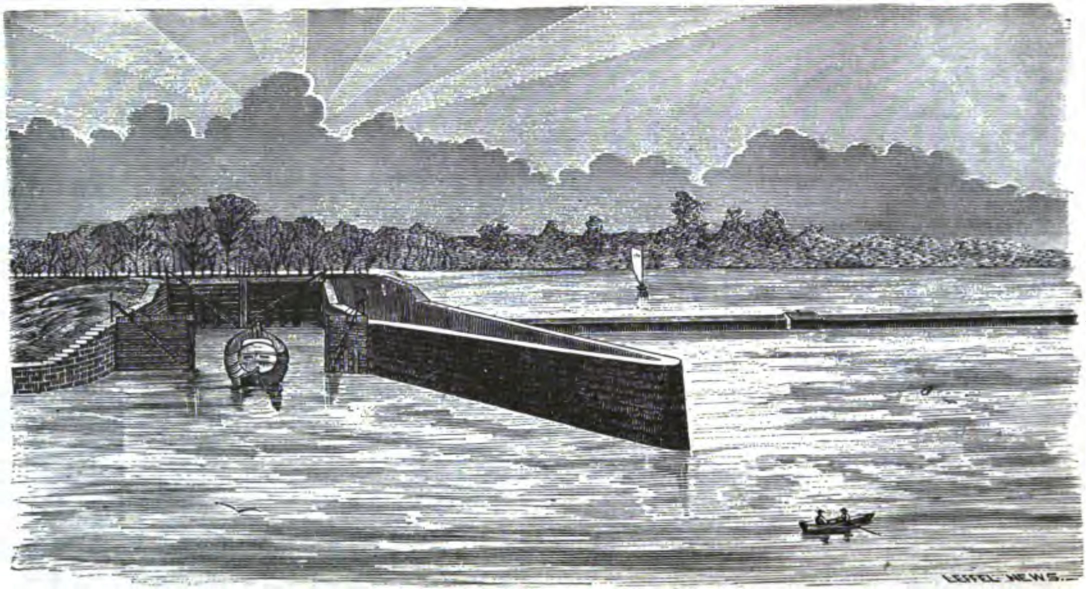
CHAPTER XXII.

LOCK AND DAM AT HENRY, ILL.

We have described in preceding chapters the construction of dams for the utilization of water power, for the measurement of streams, and for the provision of a supply of water for the use of the inhabitants of a populous city. We now give illustrations and a general descriptive sketch of a dam, the object of which is to improve the navigation of one of our Western rivers and afford, eventually, a channel of traffic between the lakes and the Gulf of Mexico, which will be of immense value to the people of our great grain growing States. The most urgent need of the agricultural population of the Mississippi and Ohio valleys is cheap transportation for their products, by which the value of their wheat and corn shall not be wholly absorbed by the charges paid in getting it to a good market. As the case stands, the railroads do not afford this indispensable means of conveyance at a reasonable cost; and without discussing the question where the fault, if any exists, is to be found, we may safely say that no greater blessing could be bestowed upon the people of the West than direct communication by water with the great centers of commerce.

With a view to securing this most desirable end, the State of Illinois has undertaken to improve the Illinois river so as to make it navigable for the largest class of steamers that traverse the Mississippi river at all navigable seasons of the year, from the mouth of the Illinois up to Lasalle, the point where the Illinois and Michigan canal enters, 100 miles southwest from Chicago. The distance thus comprised is 230 miles. The improvement is effected by the construction of locks and dams, thus forming a slack water navigation. The locks are 350 feet long between the gates, and 75 feet in width, and the dams are raised so as to make a uniform depth of 7 feet of water for the entire distance at all seasons. Formerly, during low water, there was less than three feet of water on many of the bars in the river, and on one only 16 inches.

For the entire improvement, from Lasalle to the mouth of the Illinois river, five locks and dams are required, the total cost of



LOCK AND DAM AT HENRY, ILLINOIS.

which is estimated at $2,200,000, being less than $10,000 per mile for the 230 miles comprised in the work; and this certainly appears a moderate expenditure for the facilities of transportation thus to be secured. One lock and dam was finished some time since, at a cost of $400,000. This is the work illustrated in our engravings, its location being at the town of Henry, 28 miles below Lasalle and 32 above Peoria, the second largest city in the State. The lock is on the north side of the center of the river. The dam connects with an outside protection wall, about 100 feet above the upper gates, and a short distance above the bridge erected not long since at this point; and joins the south bank midway between the bridge and the mouth of Sandy Creek.

The two smaller engravings of the three which we here present, give front and sectional views of the dam, the top of one of which may also be seen at the right of the larger cut. The dam is built of timber cribs filled with loose stones. It is 35 feet wide, 11 feet high, and 540 feet long, and is raised 6 feet above low-water mark. On the upper side of the crib-work sheet-piling is driven into the bed of the river to a depth of about 5 feet, and on the lower side piles 12 inches square are driven close together, 10 feet into the bottom of the river. Twenty feet of the width of the dam has a coping of timber, sloping up stream, 8 inches thick at one end and 4 at the other. There are two drops of 3 feet each on the lower side, with solid timber aprons twelve inches thick, and 7½ and 8½ feet width on which the water falls. Below the lower apron and the square piles, stone and brush are extended 20 feet on the river bed, and above the dam for 50 feet it is filled in with brush and gravel, tapering over on to the upper slope of the timber coping. The dam is securely bolted at every crossing of timber, and there were used in its construction more than 20,000 lbs. of wrought-iron bolts, generally ¾ inches square and 14 to 22 inches long.

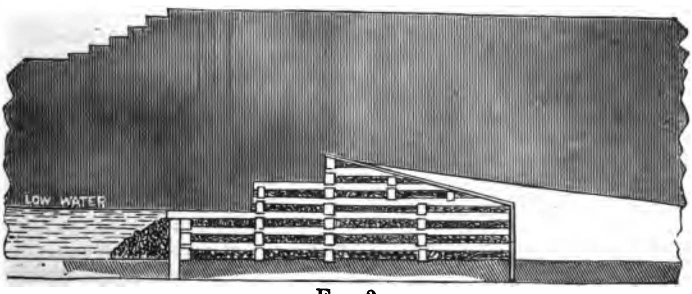


FIG. 2.

In our illustrations, Fig. 2 gives a sectional view of the dam, showing distinctly all the parts as above described. In Fig. 3 is given a front view of the dam such as would be obtained by standing midway in the

stream below the dam and looking up stream. By comparison of the two figures, the different parts will be readily identified.

The lock is built entirely in the bed of the river. In commencing the work an area of a little over seven acres was inclosed by a coffer-dam substantially built of piles with cap timbers, and of sheet piling driven outside from 6 to 10 feet into the bed of the river, and protected with gravel on the outside of the piling from the bottom of the river, with a suitable outside slope. The water, which averaged only four feet in depth over the whole area at low water, was removed by a rotary clam-shell pump, with an iron delivery pipe 9 inches in diameter, and driven by a 15 horse-power steam-engine. The area of pit to be excavated for the foundation of the lock was 485 by 115 feet, and averaged 6 feet deep, requiring the removal of 13,000 cubic yards of earth. After the excavation was made, 3,200 bearing piles of hard wood, from 12 to 25 feet long and 12 inches in diameter at the large end, were driven over the bottom. On these piles eleven rows of square timbers, 12 by 12 inches, were placed longitudinally, each row extending 477 feet, and secured to the piles with bolts 22 inches long and ¾ inches square. On these timbers cross timbers 12 inches square were placed 6 inches apart, covering two-thirds of the whole area, and bolted to the piles and the longitudinal timbers at every crossing with bolts ¾ inches square. All the spaces from the top of the cross timbers to 3 inches below the bottom of the longitudinal timbers—a depth of 27 inches—were filled with concrete. The whole of this foundation was covered with 2½ inch planking secured to the timbers.

On this substantial foundation the side walls of the lock were commenced, extending 476 feet on each side, with a mitre sill wall under the upper gates, and a breast wall at the head uniting with both side walls, which are 73 feet apart at foundations through the lock chamber. For 176 feet from the head of the lock the walls are 30 feet high, and for the remaining 300 feet 24 feet high; the upper end of the lock being 6 feet higher than the lower end, on account of the extreme depth of the water in time of floods. The main walls of the lock, where the height is 30 feet, are 11¾ feet thick, while those 24 feet high are 10¾ feet thick at the foundation. The breast wall is from 7 to 8 feet thick and 7 feet, 8 inches high. The mitre sill wall is of the same height, and from 10 to 15 feet thick; and in this wall are eight arched culverts 5½ feet wide and 3¼ feet high, through which water is admitted into the lock. Below the lower gates the main walls extend 20 feet, with wing walls 40 feet long on both sides, flaring 10 feet each at the lower end. The water is discharged from the lock through semi-circular arched culverts 5 feet wide, with abutments 6 feet high, and connected at the top with an arch of 2½ feet radius. The masonry is composed of magnesium limestone and is very substantially put up, laid in the best quality of hydraulic cement mortar; and amounts in all to 10,328 cubic yards. The entrance to the lock is formed by heavy rubble walls extending up from the head of the lock on each side. On the north or shore side it turns with a curve towards the shore, and joins a slope

wall protection to a guard bank, which extends 350 feet to connect the lock bank with the shore. On the south, or river side, this wall extends 100 feet, flaring out from the line of lock walls; then, forming a circular pier-head of 8 feet radius, it extends down parallel with the lock walls (the faces of the two walls being 50 feet apart at bottom) to 100 feet below the end of the lock, where it forms a pier-head similar to the one at the upper end, and returns to join the wing wall of the lock. The entire length of this wall is 900 feet on the river side, forming the abutment to the dam and the river protection to the lock. It is from 20 to 29 feet high, 7 to 8 feet thick at bottom, and 3 feet thick on the top, with a stone coping 9 inches thick. At the foot of the lock, on the shore side, is a similar wall extending down 50 feet and then curving towards the shore. This wall is but 15 feet high. The rubble walls

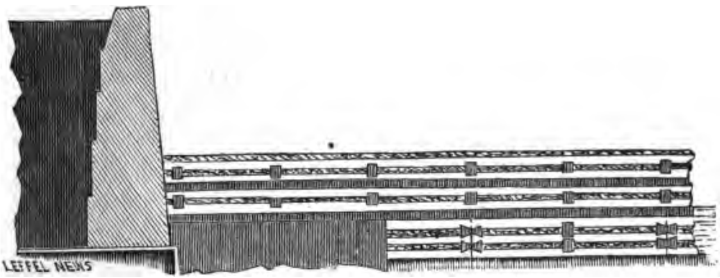


FIG. 3.

are all on a foundation of piles, timber and planking, there being 860 piles, from 12 to 19 feet long. There are 5,560 cubic yards of rubble wall, of which 5,300 cubic yards are laid in hydraulic cement, and 250 cubic yards are laid dry.

The filling between the outermost or river wall and the wall of the lock with its wing extension, is not shown in our engraving, the space being represented as if hollow, thus showing the interior or bank side of the wall, as it appeared before the filling was put in.

The lock gates are of massive proportions, 24 feet high and 43 feet wide, each gate containing over 20,000 feet, board measure, of the best white oak timber, and 27,000 lbs. of wrought and cast iron (including the anchor irons by which the gate is secured to the lock walls) weighing over 60 tons, and costing, with the hanging fixtures, \$4,000 each. The mechanism for operating the gates and for admitting and discharging the water is all of the strongest and most complete description, and the balance of the gates is so perfect that, ponderous as they are, two men can open or close them in four minutes with ease. The lock can be filled or discharged in three minutes, moving at its maximum lift 172,000 cubic feet of water. A single boat can be locked through in about fifteen minutes, a fleet requiring more time, as the boats have

to be got into position in the lock. The capacity of the lock is equal to 12 canal boats at one time, of the size of those on the Erie or the Illinois and Michigan Canal.

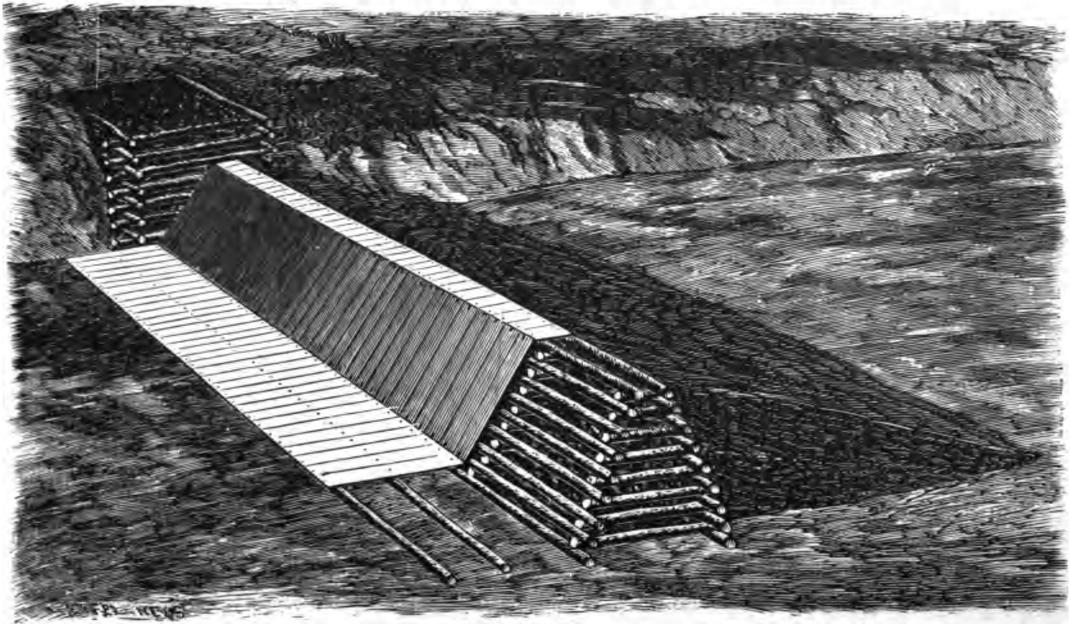
This extensive work was completed January 11, 1872. It was prosecuted under the official charge of Messrs. Joseph Utley, Virgil Hickax and Robert Milne, canal commissioners, the designing and construction being the work of Daniel C. Jenne, chief engineer, assisted by Geo. A. Keefer, John S. Butler and Charles C. Upham; and the details were faithfully carried out by the contractor, William Johnson. The stone was obtained from the Semont and Joliet magnesium limestone quarries, the oak and pine timber from Michigan, and the other timber and piles from the immediate vicinity of the work.

By the building of this lock and dam, 60 miles of good navigation is added to the Illinois and Michigan Canal. It is intended eventually to extend this work to Chicago, by improving the river in a similar manner 60 miles to Joliet, and enlarging the Illinois and Michigan Canal to the Chicago river for 36 miles. It is estimated (February, 1873) that this will cost over $16,000,000, but the money will be well invested in an enterprise so vastly beneficial to the people of the west and southwest, giving to them, as it will, direct communication from Chicago by large steamers to New Orleans and to all points on the Mississippi river and its chief tributaries. A total of 1,500 miles of navigation will thus be secured, and a cheap channel of commerce opened for an almost boundless agricultural region, which needs for its complete development only the means of transporting its products at small cost to the distant points where a remunerative market awaits them.

CHAPTER XXIII.

CRIB DAM WITH PLANK COVERING.

Crib-work, when properly constructed, with suitable filling and secure fastening of the timbers where they cross, is as reliable an arrangement for a dam as any that can be mentioned. It of course requires the use of a considerable amount of timber, there being, from the nature of the structure, no chance to economize in this respect; but as crib-work can be put up in a thorough manner with the employment of but very little skilled labor, the saving in this point is often much greater than the reduction in cost of material would be by adopting any other plan. Moreover, even in a country not heavily timbered, there is apt to be in the vicinity of a water-course a sufficient amount of such timber as will answer for crib-work, with a little management; and the builder need not therefore, in most cases, resort to an unsatisfactory style of construction, or pay high wages to expert professional workmen, unless



CRIB DAM WITH PLANK COVERING.

an unusual scarcity of timber prevents him from adopting such a method as is described in the present chapter.

The plan of dam here illustrated is suited to comparatively narrow streams, not exceeding 100 feet in width, and where not over 10 feet head of water is to be afforded. The material used is timber, brush and loose rock, with an admixture of fine or coarse gravel or coarse sand and dirt. The crib is a continuous one, from bank to bank, the timbers crossing the stream being spliced together where required. At intervals of 8 or 10 feet timbers are placed crosswise of the dam, in the direction of the stream, their purpose being to bind the frame together. They are firmly secured to the longitudinal timbers with either pins or spikes. They diminish in length from the base to the top of the dam, as the up-stream and down-stream sides of the dam have each a slope which brings them nearly together at the top. The filling may be of brush and clay, though gravel is preferable to clay under all ordinary circumstances. In this case, as the dam is intended to be as nearly water-tight as may be, the clay will serve very well to give weight and solidity to the crib-work. For the purpose of excluding the water, the dam is covered tightly with plank on both sides and on the top; and an apron of planks, supported on logs, is also placed in front of the dam down stream.

For abutments, square cribs are built, of the same general nature as the dam, but of somewhat greater width and height. The cribs should be filled with stone and gravel, and thus made as heavy and substantial as possible. It is an excellent plan, also, to give the dam a curve up-stream, as shown in several preceding chapters, its strength being thus considerably increased.

The dam in our engraving is supposed to rest on a hard bottom; but should the bed of the river be soft, it would only be necessary to put down in the first place a foundation of logs, laid close together, lengthwise of the stream, and projecting beyond the base of the dam down-stream.

Should leaks occur in the plank covering of the dam, it may be made tight by stirring saw-dust or fine tanbark into the water above the dam. A small leak at the bottom may be stopped by crowding straw or fine brush into the hole and covering it with earth. The exact locality of such a leak may be found by stirring a little saw-dust into the water near the bed of the stream and observing where the current carries it through. For a larger leak, the best plan is to put in first a stone nearly large enough to fill the hole, following it with smaller stones and finally gravel and loam. This has the advantage of being more durable than the straw filling, which will rot in time.

Although relating to a different style of construction from that above described, we may venture to add in this connection the following letter on the subject here treated of, received some time since by the publishers of this work:

"Editor Leffel News: My model of a dam is a common barn roof placed across the stream; the eaves—the upper one especially—sunk

to a solid foundation, the peak or ridge extending level from bank to bank across the creek. Or the half of the roof down the creek may be omitted, and let the surplus water drop perpendicular on an apron. (I adopt the roof as an illustration as being so easily understood, the bearers being in place of the rafters, and the planking in place of the roof boarding.) The bearers should be supported by plates running across the stream, except at the foot, where they should be beveled and rest on the bed of the creek. The plates may rest on stone walls, log cribs, or posts standing on mud-sills that have been well bedded and in the direction of the stream. The strength of timber and distance apart must be in proportion to the height of the dam. There are dams near here in rapid streams, the foundations of which have been in for over one hundred years. WM. C. CRAWFORD.

MILFORD, PIKE COUNTY, PENNSYLVANIA.

We think a sloping face on the downstream side of the dam, with an apron to carry the water fairly away, is preferable to allowing the water to drop perpendicularly on the apron. It is at the foot of the dam, in front, that undermining, wearing and washing out very frequently occur, by eddies and reacting currents of water. If the water comes down in a sloping direction to the apron, as in the dam which we illustrate, or as in the "roof" construction suggested by our correspondent, the danger referred to is almost entirely removed.

CHAPTER XXIV.

PLANK DAM AT GILBOA, OHIO.

In the dam which we illustrate in this chapter, a combination is presented of the plank construction with stone and dirt, or gravel, for the interior filling, the latter giving the dam its requisite weight and solidity. A near approach to the construction here shown was that of the dam described in chapter X, in which two tiers of plank are erected; but the manner of laying them is materially different from that here represented, as in this instance the wide base and narrow top, or the pyramid construction, so to speak, add very greatly to the firmness of the structure, rendering it hardly possible for any direct pressure to force it from its foundation.

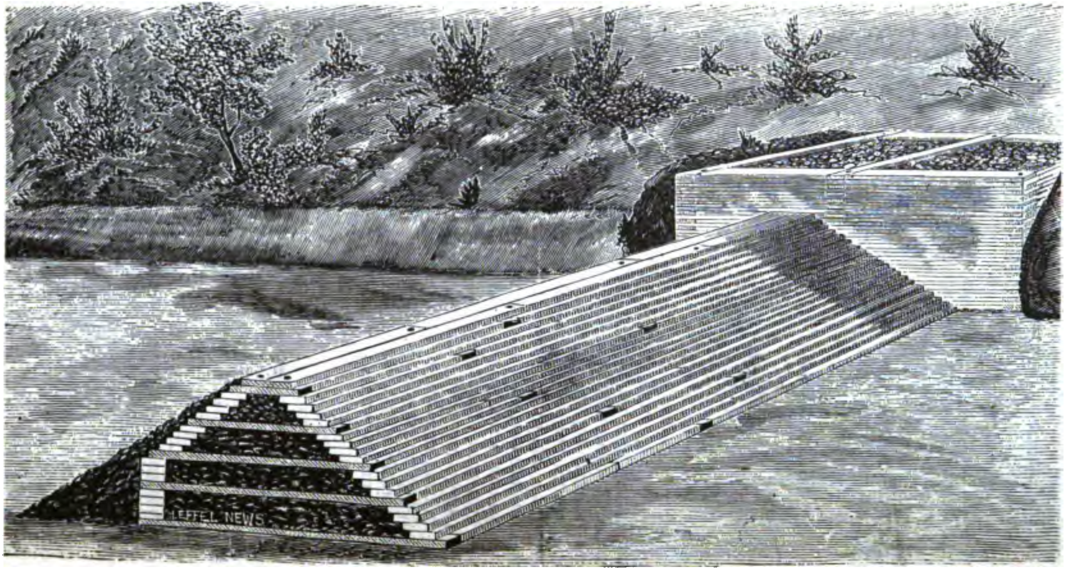
Our engraving does not represent a merely theoretical style of construction, but is a view of a dam built for supplying the power to a Leffel wheel running the grist and saw mill of A. D. McClure, Esq., located on Blanchard River, in the town of Gilboa, Putnam Co., Ohio. The stream at this point is 250 feet wide and has a rock bottom. The perpendicular height of the dam is six feet. It is shown in the cut as if cut across in the direction of the stream, showing the ends of each tier of plank, the cross-ties connecting them, and the filling between

the tiers. The planks used in the construction are 10 inches wide, 2½ inches thick, and of any convenient length; care being taken in laying them up to break joints. The cross-ties extending from one tier to the other are planks of the same thickness as those in the two walls, but may vary in width, while their length is of course determined by the distance between the tiers. They are put in at every 8 or 10 feet, or thereabout, of the length of the dam, their ends coming out between the ends of two planks which meet in the tier, and flush with the outer face of the dam. Their thickness being the same as that of the other planks, a close joint is thus made and the dam remains tight.

The planks in each tier are so laid as to fall back two inches at each successive course or layer, a continuous slope thus being given to the face of the dam, at an angle of about forty-five degrees. This falling back does not begin, however, on the up-stream side, until about half the height of the dam has been reached, the first three feet of this tier being perpendicular. The slope then commences and continues at the same angle as the down-stream face, each layer of planks falling back two inches, until the crest is reached, where the top layers of each tier are placed side by side, as shown in the cut. It may be well to surmount these with a single plank as a cap or cover, so that there will be no open joint along the crest of the dam. Built in this manner, the entire width of the base of the dam, from out to out, will be about ten feet, of which six feet or more will be on the down-stream side of a point directly under the crest of the dam, the continuous slope being on that side.

For fastening the planks either pins or spikes may be used, but pins are preferable, as, being of wood, they admit of planks being readily sawed out when repairs are required. The planks in the down-stream tier are of oak, while in the up-stream tier sycamore and elm are used below water, and oak above. Sheeting, or even round poles, may be put on the top of the dam on the up-stream side, if desired, to guard it from ice and driftwood. The whole upper side of the dam, indeed, may be covered with cement to make it perfectly tight. Still another additional means of protecting the up-stream tier of the dam is to build a wall directly against and of the same height as the perpendicular portion of that tier, which in the dam under consideration is the first three feet of the tier. This may be done if stone is abundant and easily obtained in the locality where the dam is built, but the necessity for it is not sufficiently urgent to warrant any heavy outlay, such as would be required if the stone were to be brought a considerable distance.

The dam built by Mr. McClure is abutted at one end against the stone wall of the mill; the other end extending into a square crib about ten feet high and built of the same material—2 or 2½ inch planks—and in the same manner in all essential respects as the dam itself. It is about twelve feet square, and filled with stone. The crib in our engraving is shown as projecting considerably beyond the base of the dam, as we regard it very desirable that a crib should extend two or three feet beyond the dam on both the up-stream and down-stream sides. If the



PLANK DAM AT GILBOA, OHIO.

dam, therefore, has a width of ten feet at the base, as in the case here described, we would give the crib a width of at least fourteen feet, thus allowing a projection of two feet beyond the dam in both directions.

Care should be taken to make the dam as tight as possible on both sides, avoiding any cracks or gaping joints in the tiers of plank or at the points where the ends of the cross-ties occur. The filling between the tiers, in Mr. McClure's dam, is stone and dirt. Gravel, either fine or coarse, may be used instead; or stones of irregular size, from boulders down to small cobble-stones, mixed with loam and a moderate amount of clay—the more stone and the less clay, the better. We have shown in our engraving a filling of stones, earth and brush against the up-stream side of the dam. If sheeting, cement, or a breast work of stone is put on this side of the dam as above suggested, the filling will not require to be so heavy or so carefully put in as would be necessary if the dam were in no other way protected.

The construction thus fully described is intended for streams having a rock bottom. If the bottom is soft, a foundation must first be laid, for which purpose logs placed close together, side by side, lengthwise of the stream, constitute the most reliable material. They should be long enough to project beyond the base of the dam both up and down the stream, but especially down-stream, in which direction they should extend far enough to form an apron to the dam; and this apron may be covered with plank so as to render it still more secure against the undermining action of the water. It will be observed, however, that the continuous slope of the down-stream face of the dam has a very advantageous effect in preventing the reacting, eddying and undermining tendency of the water, thus making it much less destructive to the apron and foundation of the dam. The filling or other protection for the up-stream side and upper slope of the dam would be substantially the same for this as for the dam on rock bottom.

CHAPTER XXV.

FRAME DAM AT CLIFTON, OHIO.

We illustrate in this chapter a dam which has been for some time in use, located on the Little Miami River, near the village of Clifton, in Greene county, Ohio. The course of the Little Miami in the region of Clifton, as many tourists from distant States are well aware, is remarkable for the picturesque scenery which it presents. The towering cliffs, deep gorges and shadowy ravines which have made this locality a favorite resort of pleasure-seekers for many years, fall short of actual grandeur and sublimity only when compared with the bolder natural features of the Eastern or far Western portions of the continent. In the absence of mountain ranges, which are necessary to the display

of such heights and depths as are sufficient to strike a traveled observer with awe, this charming spot is as well entitled to be called a Switzerland in miniature as any thing which Ohio or the prairie States can boast.

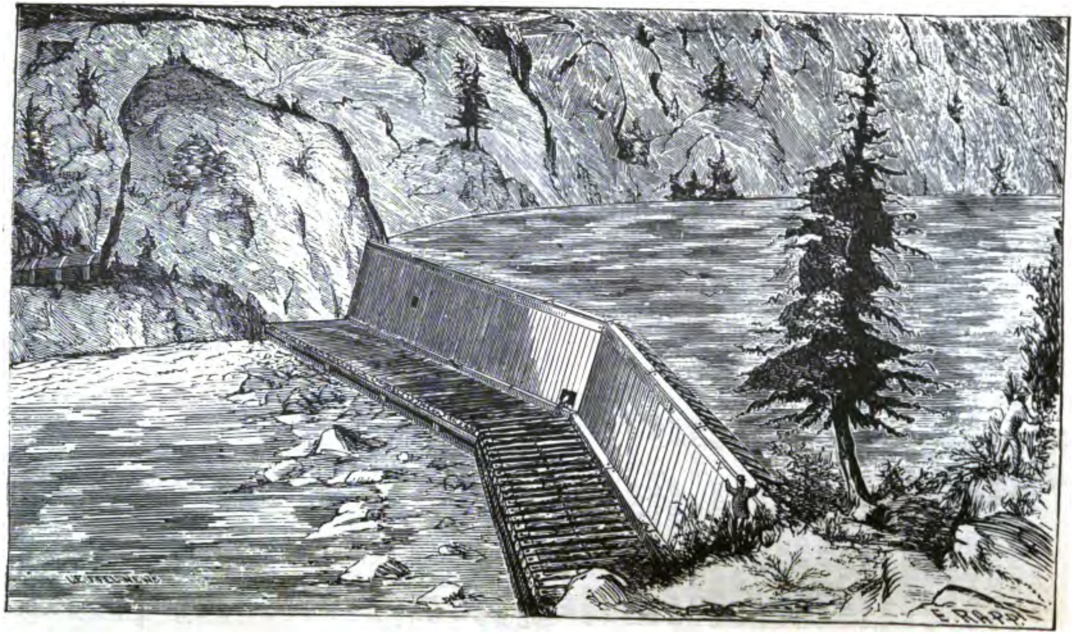
At the point where the dam here illustrated is built, the stream has a much wider bed than immediately above or below, so that the length of the dam is about 100 feet. The bottom is solid rock, and the cliffs on either side rise to a height of 70 or 80 feet. A rock against which the dam abuts on the right bank is itself nearly 40 feet high.

The foundation of the dam consists of six sills, 10 by 14 inches, crossing the stream, and placed from 6 to 8 feet apart, being somewhat nearer together under the apron than beneath the main structure of the dam. The ends of the sills are mortised into the rock at each bank, the sill farthest up-stream being also imbedded in the rock for its entire length. Across these sills are laid timbers 10 by 14 inches and about 40 feet long, the distance between centers being about 6 feet. They are secured to the lower or foundation sills by 1¼ inch barbed iron bolts, 2 feet long. Both these courses or layers of logs are squared on the top and bottom. The two center sills running lengthwise of the stream, and situated at the angle of the dam, are bolted together.

The breast of the dam is raised at the fourth foundation sill, counting from the up-stream side. The upright posts constituting the front of the dam are 12 inches square, about 15 feet long, and have an inclination from perpendicular of nearly 3 feet up-stream. The posts at the center or angle of the dam, like the two upper sills at that point, are set close together and bolted to each other. The whole number of posts is the same as the number of upper sills, and they are placed the same distance apart, each post resting on a sill, into which its lower end is mortised. Upon the top of the posts, crossing the stream, is a cap timber 12 by 14 inches. This cap timber is in four pieces, each 25 feet long, spliced where they connect, and mortised into the rock at each bank. The upper ends of the upright posts are mortised into the cap timber.

The rafters composing the up-stream slope of the dam are 10 inches square and some 25 feet long, and equal in number to the posts—each rafter, with its corresponding post and the interior braces, constituting a "bent." The rafters are mortised into the cap-timber, and between them are short cross-timbers or ties, 10 inches square, mortised into the sides of the rafters, and flush with their upper surface. The same description of ties are placed between the upright posts. The purpose of these ties is to give firmness to the frame, and prevent any tendency of the bents to sway or spread to or from each other. There are three of these ties between each pair of rafters and two between posts, so that each bent is connected with the next by five ties, the distance between the ties being from 6 to 8 feet. The foot of each rafter rests upon one of the upper sills, and a bolt is driven through the rafter and upper sill to the foundation sill of the dam.

This slope of the dam is covered with two coats or courses of 2-inch oak planks, jointed in the usual manner, the first course being laid crosswise of the stream, and the second or top course lengthwise, in the



FRAME DAM AT CLIFTON, OHIO.

same direction as the rafters. The planks are secured by spikes, and the top course footed at the lower ends of the planks against a sill running across the stream the whole length of the dam.

In the interior of the bents are braces 10 inches square, mortised into

FIG. 2.

the posts, sills and rafters, in the manner and position indicated in Figure 2 of our engravings.

The apron is constructed by placing transverse or cross sills upon the longitudinal or upper sills of the dam, these cross sills being three in number and about 6 feet apart. Upon these sills are laid timbers of the same size, lengthwise of the stream, hewed on two sides and laid close together. These logs, forming the apron, are 17 feet long. At their upper ends, where they meet the breast of the dam, a cross-timber is laid on, running the whole length of the dam, and beveled on its front so as to leave its top only 2 inches wide. The cap-timber at the top of the posts also projects 2 inches, and the 2-inch planks constituting the face of the dam, which are spiked in an upright position upon the posts and cross-ties, make with the 2-inch projections at their top and bottom, against which they rest, a continuons smooth face to the dam, giving the water an unbroken and even fall.

All the sills, rafters and ties composing the frame work of the dam are of white oak, secured by iron bolts.

The interior of the crib-work composing the apron is filled compactly with stone. The interior of the dam is also filled with stone, about half-way to the top; and against the up-stream slope of the dam is a filling of gravel and clay, extending from some fifteen feet above the dam to a point half-way up the slope, thus covering the entire lower part of the planking.

The ground plan of the dam is such that it makes an angle with the apex up-stream, instead of the arch or curve often used. The angle is but a moderate one, the center of the dam being but about 4 feet farther

up-stream than the ends, while the entire length, as already stated, is about 100 feet. As will be seen by the dimensions already given, the base of the dam, inclusive of the apron, has a total length of about 40 feet.

Near the center of the dam is a waste-way regulated by a sliding gate on the upper side of the dam. The door of the waste-way is indicated in the cut near the base of the dam, close to the center posts.

The height of the dam from the apron up to the crest is about 14 feet, the 15 ft. posts having a slight inclination, as already stated. The height from the rock bottom to the top of the dam is 17 feet or thereabouts, the top of the apron being 3 feet or more above the rock.

The water enters the forebay behind the large rock on the right bank of the stream, and only a portion of the forebay, consequently, is shown in our engraving. The race passes through an opening in the rocks, and the framework of the head-gates is mortised at both ends into the solid rock.

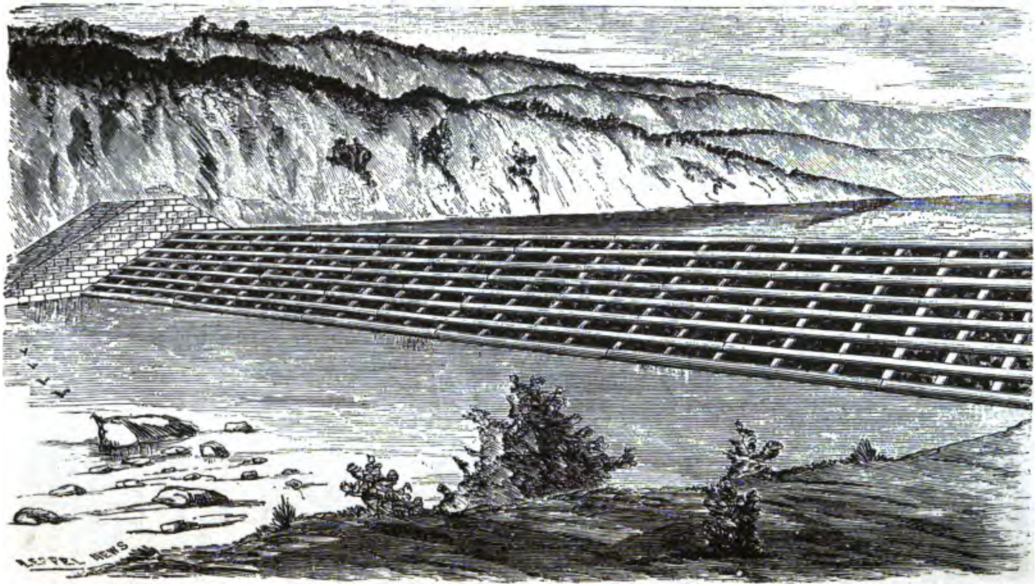
This dam was built some years since by Messrs. King & Hagar, at that time proprietors of the Clifton Paper Mills, now carried on by Col. David King. A general view of the dam is given in our principal engraving, and in Figure 2 is represented a cross-section, showing the upright post, rafter and braces constituting a bent, the two courses of plank on the up-stream slope, the end of the timber against which the upper course is footed, the upright planking on the face of the dam, the ends of the cap-timber above and the beveled timber below, and also the ends or sides of the various sills composing the foundation and the crib-work of the apron.

As the region in which this dam is situated is visited every year by large numbers of tourists, many of our readers may already have examined the structure above described, or may have opportunities of doing so in future. At a favorable season of the year, a more attractive spot can hardly be found, though there are many of wider reputation and more favored by the patronage of the wealthy and fashionable.

CHAPTER XXVI.

TIMBER DAM AT NEW HARTFORD, CONNECTICUT.

The durability of the dam which we illustrate in this chapter has been proved by a period of service dating back farther than the birth of many of our readers. It was built in 1847, and has therefore stood some thirty-four years, requiring in all that time but little repair or alteration. It extends across the Farmington River at New Hartford, Conn., and, as will be seen by our engraving, is built of timber, no other material being used except that required for filling or staying the



TIMBER DAM AT NEW HARTFORD, CONNECTICUT.

structure, and for the abutments as will be hereafter described. The timbers used are from 9 to 12 inches in thickness, the first or foundation tier being laid crosswise, the second tier lengthwise of the stream; and this arrangement is continued throughout, the alternate layers crossing each other until the work is brought to the desired height. When complete, it has the form of a pyramid, the sides presenting an angle of 27 degrees with the horizontal line or bed of the stream. This angle of the sides gives the base such ample width in proportion to the height that, taking this in connection with the pyramidal form, the dam has a degree of solidity and strength in its very shape which ensures its durability.

The timbers are fastened, at each point where they cross, with a spike of ¾-inch round iron, 20 inches long. The water side is covered with planking of 3-inch oak and chestnut, jointed, and put on with 7-inch cut spikes. The timbers running lengthwise of the stream are placed 6 feet from center to center, the ends coming out flush with the face and back of the dam. The timbers running crosswise of the stream are so placed as to give from two to three feet in the clear; and all the spaces are filled with stones, from the foundation up to the cap-log.

On the lower or down-stream side of the apron, piles are driven and securely fastened to the lower mud sill, on which the apron partially rests. The apron is composed of timbers 12 inches thick, placed close together. In order to attach the apron firmly to the main structure of the dam, the following plan is adopted: once in every six feet of the apron a timber longer than the others is put in, extending up-stream under the dam a distance of 25 or 30 feet, while the other apron-timbers run only 2 or 3 feet under the first timber of the dam proper. By this means, without putting more timber into the apron than is absolutely required, it is nevertheless held so firmly to the main structure of the dam that no danger of separation exists.

The entire length of the "rollway" is 232 feet. The height of the dam, from the bottom of the mud-sills to the top of the cap-log, is 21 feet. The width at the bottom, from the foot of the dam to the up-stream side, is 68 feet; and the apron projects 14 feet beyond the foot of the dam.

The river bottom at this point consists of cobble-stones, gravel and quicksand. The banks are gravel and sand. The gravel is of the kind known as "washed," it being devoid of all the fine admixture which renders a bank tight against water. On the upper side of the dam is a filling of gravel to within 4 or 5 feet of the cap-log. It is not uncommon for the stream to rise to such a height as to give six feet of water on the cap-log; and a depth of even 10 feet at that point has been known, but is of rare occurrence. The capacity of the river at this place is stated at 14,525,000 cubic feet of water every 24 hours during an ordinary drought.

Our present illustration gives a perspective view of the exterior of the dam, showing also one of the abutments, which are of solid masonry, and pyramid-shaped, like the dam itself. In our next chapter we shall

give a sectional view, showing more clearly the interior structure of the dam, with some additional particulars required to complete the description.

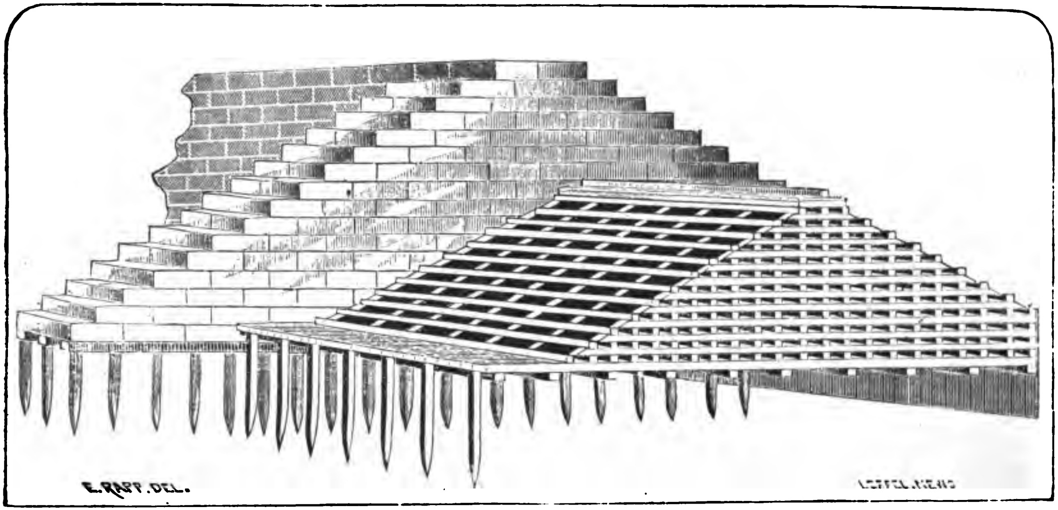
CHAPTER XXVII.

TIMBER DAM.—*Continued.*

In our last chapter we gave a perspective view and general description of the dam of the Greenwoods Company at New Hartford, Conn., comprising the dimensions of the dam, the material used, size of timbers, and the manner in which they are put together and secured. We now present a sectional view of the same dam, from which the arrangement of the timbers will be still more clearly perceived. In this engraving, also, a full view is given of several portions not shown in the perspective cut, such as the apron in front, composed of twelve-inch timbers placed close together; the piles driven on the down-stream side of the apron, and fastened to the lower mud-sill, extending into the bed of the stream to a depth of 15 feet; and the form of the abutment, the face or front portion of which also rests upon piles. Our present engraving shows but a small part of the dam, the entire length of which, as already stated, is 232 feet. In the view it is represented as if cut transversely, in the direction of the stream, showing the internal framework, but not the filling of stones in the interior, or that of gravel in the upper side of the dam.

The strength and stability afforded by the pyramidal shape of the dam will be readily seen in this illustration, the only real source of danger being from the washing out of the gravel, especially on the lower side of the dam, which is liable to occur at a time of very high water. This difficulty did in fact present itself in the case of the dam here described, during a very heavy flood some years ago. The water acted with such effect at the lower side of the apron that a considerable quantity of gravel was washed away; to remedy which the proprietors built cribs of poles and logs, and filled them with large rocks, weighing two to three tons. These cribs were then sunk to the bottom, and the whole chained to the piles at the foot of the apron; since which time no trouble from washing out has been experienced.

At a later period some repairs of the dam were found necessary, and nine or ten feet of the top was taken off, the timbers having become rotten. The cause of the rotting was ascertained to be that the dam, when originally built, was planked tight on the lower side as well as on the water side, leaving no avenue of escape for the hot steam which gathered inside the dam in hot weather. The face of the dam being to the south, the heat of the sun had a powerful effect in generating this steam in the interior, with the injurious results to the timbers



TIMBER DAM AT NEW HARTFORD, CONNECTICUT.—Sectional View.

above indicated. All the planking on the lower side was therefore removed, leaving this side in the condition shown in our engraving in the last chapter.

It is proposed (1873) to raise the dam six feet, making with the present height of 21 feet a total height from bottom of mud-sill to top of cap-log, of 27 feet. It has already been mentioned that the stream frequently rises to such an extent as to give six feet of water, and in rare instances even ten feet, on the cap-log of the dam as it now stands. The increase of height will therefore afford the means of a corresponding addition to the amount of power held in store, the present structure being hardly in due proportion to the capacity of the stream. Our engraving shows the wall as already raised. The dam or "rollway" will be raised by placing at every 6 feet of the length of the dam a frame or trestle resting, as it were, astride of the crest of the dam and very firmly secured on both the upper and lower slopes of the present structure. The water side of this additional framework will be covered tightly with 3-inch jointed plank. Upon the lower side will be placed 3-inch planks, 2 inches apart, the object of this arrangement being to ventilate the interior and give free escape to the hot steam generated as already described.

CHAPTER XXVIII.

LOG DAM FOR NARROW STREAMS.

The description and illustration which we present in this chapter were elicited by an inquiry on the subject of Mill Dams published in Leffel's Mechanical News for February, 1873. In order to present more clearly the suggestions embodied in the ensuing article, we first reprint in full from the Mechanical News the inquiry alluded to (and also the comments editorially made upon it), as follows:

"MESSRS. JAMES LEFFEL & Co.:—I desire to build a mill-dam across a hollow about 60 feet wide. Will have a slate rock foundation all the way across, and the hight of dam will be 15 feet. I have two plans for building the dam. The first is to dovetail posts in the rock about four feet apart, straight across the hollow, and nail two-inch planks to the posts, setting the posts 12 inches in the rock, and having them 15 feet high.

"My second plan (I think the best) is the following: Get me a sill 14x14 and lay on the rock across the hollow, and then put iron stirrups across the sill about 5 feet apart, placing the ends of the stirrups about 1½ feet deep in the rock and running Babbitt metal in the holes around the stirrups. Then place my posts about 4 feet apart, letting them about 1 foot deep into the sills, and having a brace running from top of post down stream, lower end on a sill. Stone is too scarce to build a stone

dam. The stream of water is only from a large spring (no creek) only 100 yards from the dam. The water, when running on mill, is about 6 inches deep in a fore-bay 3 feet wide, affording enough water to run a set of 30-inch wool cards and a grist-mill, rocks 30 inches in diameter.

"The fact is this: we want to build a good dam, without a great expense. I would say that the hollow is wider between the spring and dam than it is at the point we wish to put the dam.

"I desire you to answer this in the next number of the News. Tell us which is the best plan, and if you can let us have a better plan, please give it in your paper. You may put me down as a permanent subscriber. Enclosed find money. Trusting you will comply with my request, I am fraternally yours, W. H. W.

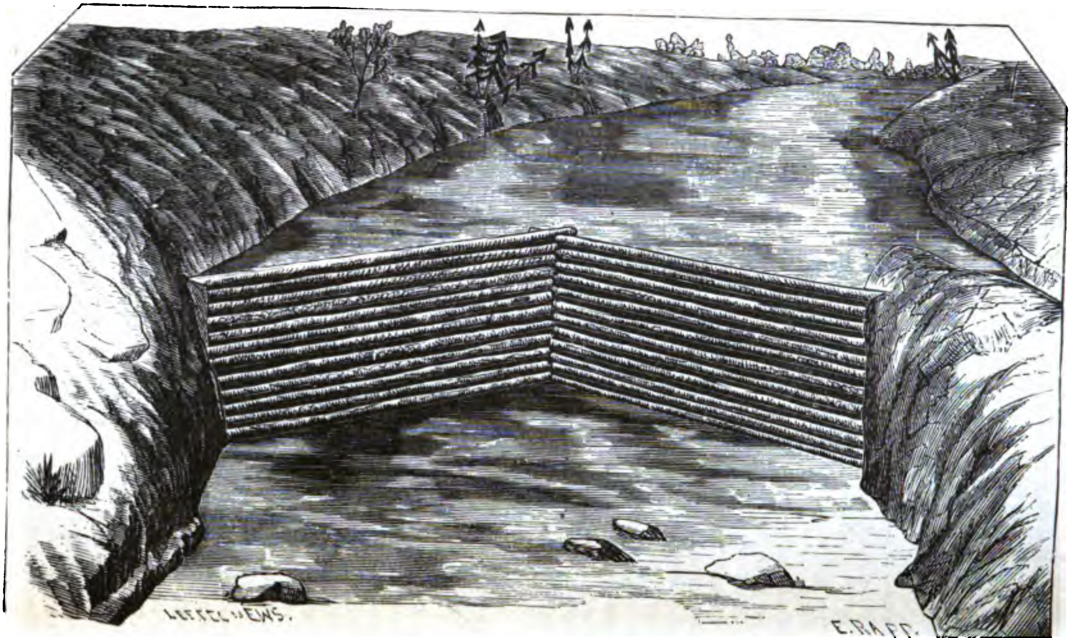
'FLYNTVILLE, TENN."

"[We do not agree with our correspondent in thinking his second plan the best, but should give the preference to his first, provided certain important amendments are made to it. The posts should be let into the rock a depth of at least two and one-half feet, and three would be still better; and they should have one or if possible two series of braces if the dam is to be 15 feet high. The general plan of the dam, as we would build it, is similar to that described in our issue for November, 1871, except that the posts in this case should be nearer together than in the dam illustrated. The reason for this is, first, that the hight of the dam is much greater, and second, that slate rock is peculiarly liable to wear away under the influence of either sun, air, frost or falling water. We shall be glad to hear from other correspondents in regard to W. H. W.'s inquiry.—ED. LEFFEL NEWS.]"

In a subsequent issue of the Mechanical News appeared a communication from another correspondent, in Wabash, Ind., over the initials "R. S.", giving a full description of a dam which he has found by practical experience specially adapted to narrow streams such as are here referred to. He also furnished a pencil sketch of a dam of this character of which he is a joint proprietor, located on Treaty Creek, Wabash Co., Ind.; and from the sketch thus supplied we have produced the engraving here presented.

Referring to the plans submitted by "W. H. W.," the Wabash correspondent remarks: "I do not like either of them; and as the editor stated that he 'would be glad to hear from other correspondents in regard to these inquiries,' I will, as an old hand at building mills and dams, suggest my plan of building dams across narrow streams, or 'hollows 60 feet wide,' as he says his is. The motto of B. Franklin has ever been mine, viz: 'What is worth doing at all is worth doing well.' Even should my plan cost a little more at first than his, it will be the cheapest in the end.

"Here it is. If the banks are stone, and have no natural jut or projection sufficient to abut the ends of the dam against, and are not too hard to cut, cut a groove in the stone embankments where the ends of the dam are wanted, about 12 inches wide, and a few inches deep, from the bottom up, and as high as the dam is to be built. Take round logs



LOG DAM FOR NARROW STREAMS.

and face two sides straight and nice, large enough to measure a foot thick when faced. Cut the logs long enough for two lengths to make the dam. Square the end that is to go in the groove at the abutment, or shape it to fit. Lay the log not at right angles across the ravine, but put the ends which meet in the middle nine or ten feet up stream above a straight line, so as to form the dam that much in the shape of a horse shoe, or rather in the form of two panels of rail fence with the lock up-stream; then halve together the ends which meet, putting the faces of the logs together as the dam is raised so as to hold the filling of gravel or dirt. Continue to so notch the logs together in the middle until the dam is the desired hight, filling up at the same time with gravel and stone if plenty; if not, dirt will do, provided the logs fit well enough to hold it. Thus we see, to build a dam in this way supercedes the necessity of any posts or braces, for it braces itself. And the harder the pressure of water and filling above, the tighter it will press the ends of the dam against the abutments, so that it can neither push out, wash round the ends, nor wash or undermine if stone bottom, and the bottom log well fitted. This plan supercedes, also, the necessity of cutting any post-holes or mortices in the bottom of the stream, or of bolting down the bottom log to keep the dam from pushing down stream.

"If not stone bluffs, then of course, abutments of either good stone or timber must be made, projecting into the banks. They should be notched up as the dam is raised, and all well filled as it goes up.

"If the bottom is slate, or any material that will not stand the force of water pouring over for many years, it should be leveled a sufficient distance up and down the stream, clear across, to receive a log apron. Face the logs on three sides, putting the square edge down. Cut them 16 feet long, and cut a gain on the top of each one 6 feet from the end that lies up-stream, 4 or 5 inches deep, to lay the bottom log of the dam in, thus letting the apron extend about 10 feet below the dam, and 5 above. The apron logs notched in this way and the dam built on them, and they fitted up together, will prevent the bottom from wearing as long as they last. And having them 12 inches thick (which they should be for 15 feet fall), they will last, if water is kept over them, many years, for they cannot wash out put in in this way, nor raise at the lower end in case of a flood of water rising over them below the dam.

"This plan of building dams is not only applicable to W. H. W.'s 'hollow,' but to all streams that are not too wide for two logs to span in a bracing way. And it makes no difference how high the dam is built, it cannot push out if the logs are stout enough not to bend edgewise and come out like a spring-pole.

We, of the firm of Small & Son, have a log dam 15 feet high, about 60 feet whole length, built precisely as I have directed, and it has been in use some twenty-seven or twenty-eight years, and not a log amiss yet; though the top is getting a little tender, and wants a new top-log. Ours are stone bluffs and solid limestone bottom, all the apron it needs. Our filling is mainly shelly limestone with some gravel and dirt; not

even sheeted on top, but would be the better of it, for the stone and gravel washes off some.

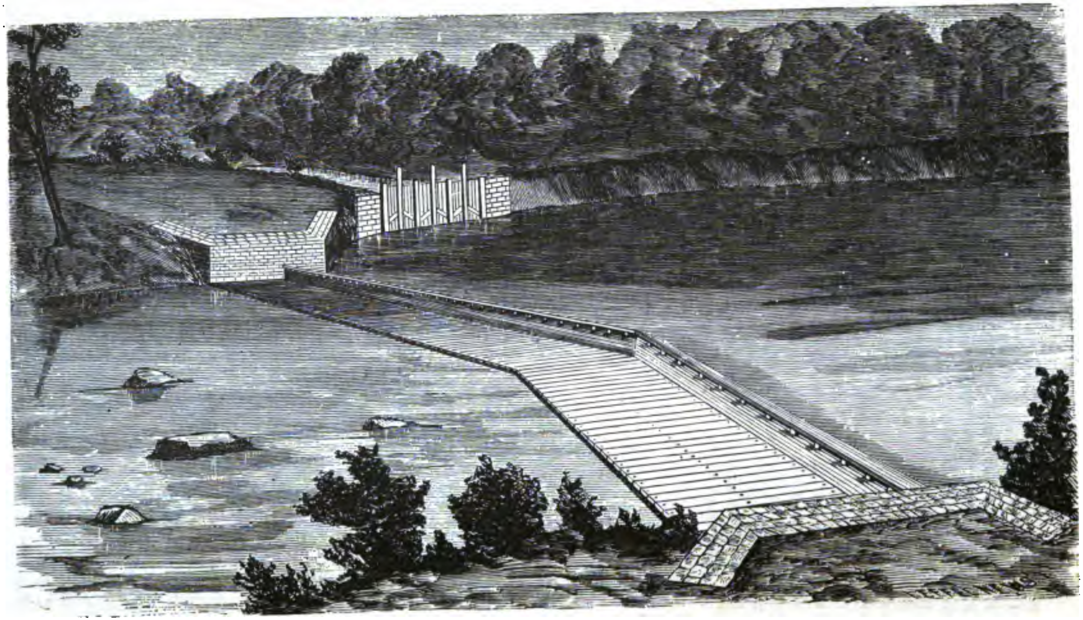
"I give a rough sketch of our dam, which is so simple that any ten-year-old boy of common mother wit can see into the philosophy of its strength and durability.

"In 1846 I helped put a log dam across the Missisinewa River, nearly 200 feet long. In 1854, I think, I put in, or rather spliced, the same kind of a dam on Deer Creek, to run a saw and grist mill. And about 1858 or '59, I put a log dam in to run two 4-feet burrs; all in Grant county, Ind. Not one of these dams has gone out yet, unless they went this winter. Though these dams were all straight, the breast is logs, and a log laid in the stream a few feet above, with dovetail ties in it and the breast logs, as they were notched up, all tied to the single log above, filled with stone and gravel, then sheeted with 2-inch plank, and graveled on the upper end of the sheeting; and with good abutments and aprons, I consider the log dam the cheapest yet."

CHAPTER XXIX.

FRAME DAM ON MAD RIVER.

We add in this chapter another illustration and description of a dam which has the advantage, over a merely theoretical plan, of being verified by actual construction, so that every detail has been worked out and may be relied on as practical, and duly adapted to the circumstances of the case. The dam here represented is built across Mad River, in Clark County, Ohio, and is 165 feet long. The stream at this point has a mud and clay bottom, upon which is a coating of sand and gravel, washed down from above. The foundation of the dam consists of sills 30 feet long, hewed flat on the top and bottom to a thickness of 10 inches, and laid lengthwise of the stream, about 8 feet apart. Upon the top of these sills, at their up-stream ends, and running across the stream, is bolted a timber 8 inches square, 16-inch bolts being used to secure it to the sills. The breast of the dam is raised to a hight of 30 inches above the apron, and is made by first laying a timber, 5x14 inches in size, across the stream on the foundation sills. On the top of this 5x14-inch sill are eight tiers of joists 3x10 inches, which are laid flatwise upon each other and spiked together with 6-inch iron nails. The face of the dam, composed of these joists, is battered or inclined up-stream 5 inches. At a point 5 feet up-stream from the cross-sill on which the joists rest is laid across the stream, and bolted to the foundation sills, a timber 8 inches square. From this sill to the top of the breast-work of joists, or crest of the dam, are laid rafters 6x8 inches, 6 feet long, and 3 feet apart from center to center. The cut required at the upper extremity of each rafter to give it a secure hold upon the



FRAME DAM ON MAD RIVER.

breast of the dam, is made about 3 inches from the end of the rafter, which therefore projects that distance in front of the tier of joists, and by this means the rafters are, so to speak, hooked over the crest of the dam. The depth of the cut is about half the thickness of the rafter, and the width 10 inches, the same as that of the joists. The rafters are pinned to the crest of the dam, and also to the sill at their lower ends, with wood pins 1½ inches in diameter.

For the covering of the dam there are laid, crosswise of the stream upon the rafters, 2½-inch planks, which are fastened to the rafters with 6-inch nails. From the foot of the rafters, also, to the up-stream end of the foundation sills, a covering is laid consisting of planks 2 inches thick, running crosswise of the stream and nailed to the foundation sills. Upon the plank covering of the mud-sills, and extending some distance up the covering of the rafters, is a filling of gravel about 2 feet in depth; and the space under the rafters, from the mud-sills up to the plank covering, is also filled with sand and gravel.

The apron of the dam is made by laying three sills across the stream, resting on the foundation sills, and secured to them with 16-inch bolts. Upon these cross-sills and the projecting edge of the 5x14-inch sill under the breast of the dam, are spiked planks 2½ inches thick, 12 feet long, and running lengthwise of the stream, as indicated in the engravings. At the down-stream end of these planks, against the side of the apron-sill and the ends of the foundation or mud-sills, are driven spiles 3x6 inches, reaching to a depth of five feet. The same is done at the up-stream end of the dam where the extremities of the mud-sills and the side of the cross-sill at that point rest in like manner against the spiles. The spiles at both the up-stream and down-stream extremities of the dam, are placed close together, forming a continuous sheet across the stream.

The abutments of the dam are of solid masonry, laid up with cement, and are 21 feet in length of face, 5½ feet in height, and 6 feet thick. In addition to this are the wings, each 10 feet long, and of the same height as the face wall. The tops of the abutments are at about the same level as the earth banks of the stream. They rest on the foundation sills of the dam, three of which are under the abutment. The filling of the space enclosed by the face and wing walls is entirely of gravel and sand.

E. B. Harvey, of Miami county, is the builder of this dam, which is located near Enon, Clark county, Ohio, and is owned by Martin Snyder. It supplies the power to run a flouring mill, propelled by Leffel Double Turbine water-wheels.

Our large engraving gives a perspective view of the dam, showing both the abutments and also a portion of the race, with the head-gates, three in number. In the smaller illustration is presented a sectional view, showing a foundation sill lengthwise of the stream; the end of the cross-sill at the up-stream extremity of the dam, and also of the cross-sill at the foot of the rafters, the one on which the breast-work rests, and the three sills of the apron; the ends of the eight tiers or layers of joists, and of the planks covering the rafters and the up-stream portion

of the mud-sills; the side of one rafter, showing the cut at one end for the foot-sill and at the other end for the crest of the dam; the plank covering of the apron, the spiles at the upper and lower extremities of the dam, and the line of the gravel filling. By the clearness with which

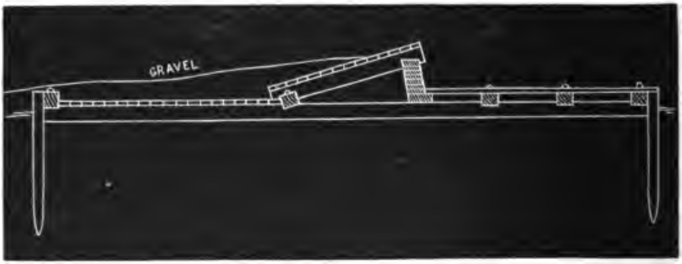


FIG. 2.

every detail is shown in this cut the whole construction of the dam will be accurately understood.

We may here state that for the purpose of keeping the water from interfering with the work upon the dam, a coffer was built at a point 5 or 6 feet up-stream from the upper ends of the foundation sills, extending from one bank nearly across the stream, and thus protecting one-half of the dam while the building was going on. To protect in like manner the other half of the dam while in process of construction, it was only necessary to remove the upper part of the coffer above the finished part of the dam, letting the water flow over both coffer and dam on that side of the stream; the material thus taken off being used to extend the remaining part of the coffer to the opposite bank, and a barrier being also built from the coffer to the inner or mid-stream end of the finished half of the dam, keeping the water from that part of the dam on which work was still in progress.

[After the foregoing was put in type, we received information that the work upon this dam, just as it was approaching completion, was interrupted in the following manner. The dam on one side of the stream having been finished, and work on the remainder being in progress under the protection of a coffer, a channel was cut from the head race through the bank behind and around the finished abutment, to carry off the water. A flood occurring, the swollen stream poured through this channel and caused great damage to the abutment and the completed portion of the dam. We presume that parties on the spot were best qualified to judge as to the course proper to be pursued; but from what data we possess, we are inclined to believe that by first putting in a head-gate at the race, and allowing the water to pass over the completed portion of the dam, the disaster might have been avoided.]

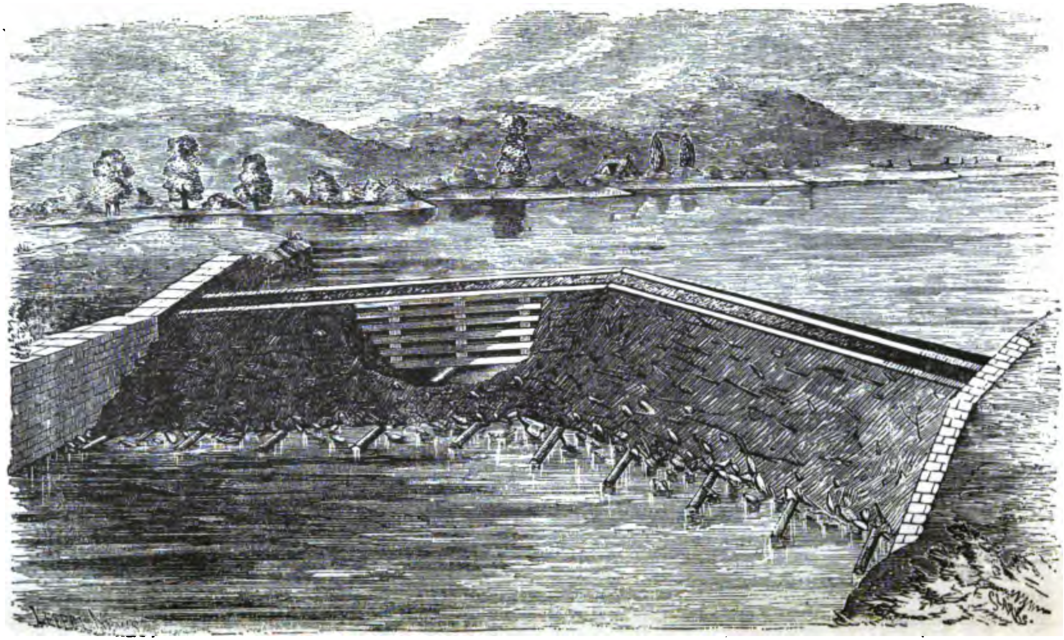
CHAPTER XXX.

DAM AT OSBORN CITY, KANSAS.

The dam herewith illustrated is constructed on the same principle, in many respects, as several which have already been described; but the plan here shown will be found in some localities to possess advantages in point of simplicity and strength which will justify its adoption by the mill-owner. It cannot be accurately classified as regards the kind of material employed, as stone, logs, sawed timbers, boards, rock, gravel, sand and hay are used in its construction, their proportions and arrangement being such as to afford, without very heavy outlay, a satisfactory degree of firmness and durability. Our engraving gives a perspective view of the dam built by Messrs. David Milne & Son, at Osborn City, Osborn County, Kansas, furnishing power by which their saw mill and grist mill are run. The width of the river at this point is 64 feet, and its bottom consists of a layer of sand about 3 feet in depth, resting on a bed of solid slate and shale. In preparing for the erection of the dam; the first step was to scrape the sand away until the solid bottom was reached. The mud-sills were then put down, consisting of logs from 14 to 18 inches in diameter, and from 20 to 28 feet long, their direction being lengthwise of the stream. Brush was also put in to aid in making the sills as firm and solid in their positions as possible. In scraping away the sand, a hollow of considerable depth was of course made; and after the sills were put down, the sand washed over the mud-sills, which thus became imbedded in sand and brush, and have thus far shown no indications of giving way. The distance between the sills is about 6 feet from center to center.

It should be stated, before proceeding further, that the body of the dam is supported at each end by wing walls, as shown in the cut, these walls being 3 feet in thickness and built solidly along the face of each bank for a considerable distance both above and below the dam.

After laying the mud-sills, as described, the next stage of the work is the erection of the crib, which is composed of sawed timbers, and rests upon the sills, extending from bank to bank, and forming, as will be seen in the engraving, an obtuse angle with the vertex up stream. The width of this crib is 5 feet and its height 8½ feet. The timbers running across the stream are 6 by 6 inches, while the cross pieces are 4 by 6 inches, placed flatwise, from 5 to 7 feet apart, and spiked to the main or longitudinal timbers, which are therefore 4 inches apart, one above the other. These 4-inch spaces are covered by nailing boards upon them, thus rendering the up-stream and down-stream walls of the crib sufficiently tight for all practical purposes. The 6 by 6-inch timbers are pinned together with 2-inch oak pins, 16 inches long. In the engraving, the dam is shown with a part of the filling on the down-stream face cut out, giving a view of a portion of the crib in the interior. The main or longitudinal timbers, the ends of the cross timbers, and



DAM AT OSBORN CITY, KANSAS.

one of the foundation sills are thus shown, also the level top of the crib, 5 feet wide, forming the crest of the dam. The ends of the foundation sills are likewise seen, projecting down stream from under the filling. Each end of the crib, at the point where it joins the wing wall, is let into the wall for a depth of 3 or 4 inches, giving it a firm and solid bearing, and rendering it, in connection with the angular direction of the two halves of the dam, abundantly strong in its position, so far as regards any direct pressure from the water above.

The filling of the inside of the crib consists of broken rock, gravel and hay, arranged in the following manner: a layer of rock, finely broken, is first put down, having a depth of 10 inches; a coat of gravel is then put on, leveling up the surface of the rock; then follows a layer of hay, then another layer of rock, and so on with alternate coats of rock, gravel and hay up to the top of the crib. The rock used is a kind of flint found in the vicinity, and very heavy. Above the crib is a filling of broken rock, gravel, hay and sand. The width of this fill at the base is 12 feet, sloping to the top of the crib. Below the crib, on the down-stream face of the dam, is a fill of rock and brush, sloping to the top of the crib, and the whole dam has thus the shape of the roof of a house. The crib is located at a point on the mud-sills about two-thirds of the distance from their down-stream to their up-stream extremities, and the front of the crib is just above the projecting corner or vertex of the angle formed by each of the wing walls. These distances and proportions are distinctly shown in the engraving.

We are of opinion that the plan of dam above described, which is an excellent one in most respects, would be still further improved by bolting the mud-sills in a few places to the rock bottom. If they were surrounded and covered by a good depth of mud, this would be less important. A mixture of sand, in liberal proportions, with the gravel in the crib, to pack and tighten the whole mass, would also be useful; although this point is very well provided for by the board covering on the side of the crib, especially if a considerable amount of fine sand and gravel is thrown against it. As for the use of hay, either in the crib or above it, we have small faith in its utility, as it will rot out after a time and require refilling. There is, in fact, nothing better than heavy gravel and sand for all kinds of filling about dams, head-gates, races, etc.—and nothing poorer than clay.

Of the light rocks and brush forming the inclined apron below the dam, a considerable portion will wash away in case of a flood; but if there are also plenty of heavy boulders, these will maintain their position, and no material damage will be done.

The builders of the dam described in this chapter, in a letter dated April 15, 1874, give the following particulars, indicating the reliable character of their plan of construction: "We have had some high water this spring. It has taken out two dams on the river, but ours is firm and all right. It is impossible to take it out, and we think it the best kind of dam that can be put in a stream that is not very wide. It has cost us a good deal, but the first cost is the cheapest in the long run.

Parties putting in dams cannot do too much work on them. They should be completed in the start, and then you know you are all right." Mention is made in the same letter of a dam several miles farther up the stream, built of rock, logs and brush, but having no wing walls, or any protection for the banks—the result being that in the freshet above referred to, the water cut around the dam and nearly ruined the work.

CHAPTER XXXI.

STONE AND TIMBER DAM.

In the present chapter we describe and illustrate a stone and timber dam which was erected in 1873 by the owner, Hamilton B. Lawton, at East Brunswick, Rensselaer County, New York. Its method and material of construction are such as to adapt it to a region where stone is abundant, as this, with a moderate amount of timber, is the article principally used in its erection. The dam is built on a rock and "hard-pan" bottom. Its length is 150 feet, and its height 22 feet, from the level of the water to the top of the upper plate. The base of the dam, measured on a horizontal line from the up-stream to the down-stream extremity, is 23 feet in extent, being nearly the same as the height; and the up-stream side of the dam, therefore, slopes at an angle of 45 degrees. This form of construction gives the necessary degree of stability, and also affords ample room for filling in between the rafters with rocks and small stones, thereby rendering the mud-sill and plate very secure in their position.

Our principal engraving shows the face of the dam and abutments, the upper and lower plate and the posts being the only timbers visible. In the smaller cut is given a complete representation of the framework, in which A is the upper plate and E the mud-sill at the up-stream extremity of the dam. The rafters B are fastened to the plate and sill with strong spikes. It will be observed that midway of the rafter B is a timber D, parallel with the plate and mud-sill; and that to this middle plate are attached short rafters C, alternating with the main rafters and having their lower ends secured to the up-stream mud-sill in like manner with the main rafters. The purpose of these short rafters is to give a more firm support to the plank covering of the dam at this point, where the pressure of the water is heaviest.

The main rafters, reaching from the up-stream mud-sill (which is bolted to large rocks) to the upper or cap plate of the dam, may consist of timbers unhewn except on their upper faces, where they should be made flat to admit of the laying of the planks, and give an even surface to the water side.

The main timbers of which this frame is composed are 12 by 14 inches. The bottom plate or sill F lies upon a series of rocks arranged,

as indicated in our main illustration, so as to form an apron to receive the overfall of water and prevent the washing, wearing and undermining of the base of the dam. The posts G are framed into the

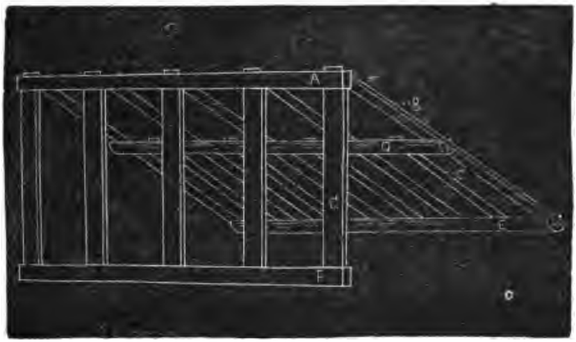


FIG. 1.

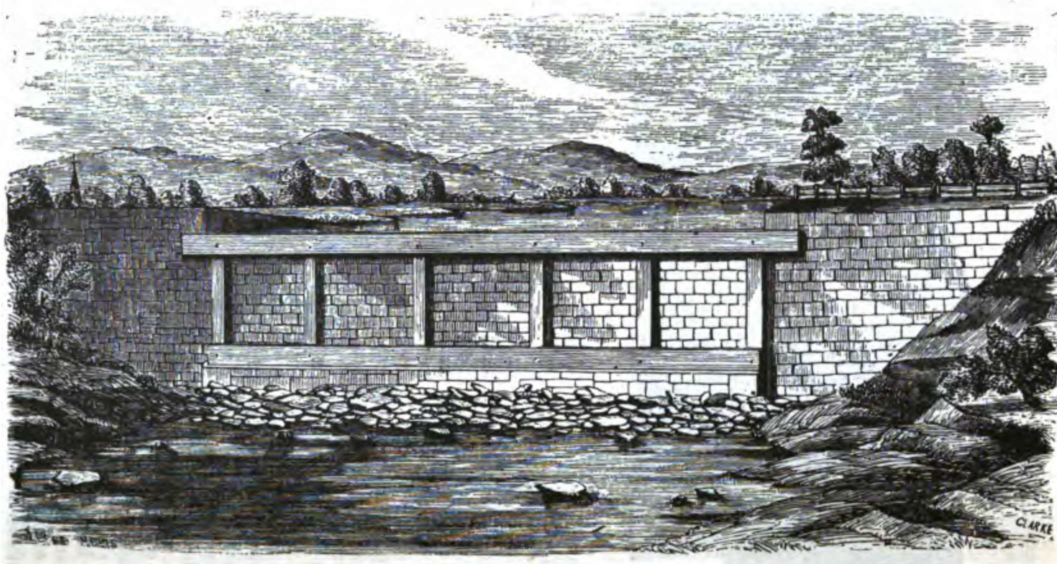
upper and lower plates as shown in both the cuts, and serve to support the upper plate in case the wall should settle in course of time, as it is liable to do to a very small extent.

The ends of the dam, on each side of the frame-work, are compactly built up with rocks and small stones in the rear, and in front square rocks are carefully laid up to present a smooth front and a permanent wall; thus allowing the timber work to be taken out and renewed, should it be necessary at any future period.

The filling in the interior of the frame-work, as already mentioned, is composed of rocks of irregular size, from heavy boulders down to cobble-stones; and the dam is covered with planking in the same manner, substantially, as described in former chapters relating to dams of this general nature.

The builder of this dam is confident that it will last a lifetime, and that very little expense will be required in repairing the wood-work. The other portions of the structure should of course demand no outlay whatever after having been once completed.

As an appropriate addition to the account above given, we may here describe briefly another dam of very similar nature to the one already shown, although in quite another section of the country. The dam to which we now refer is built across the Des Plaines river at Joliet, Ill. It is the lowest dam down the river in the city, there being two State dams above it; and is owned by Messrs. Wm. Adam & Co., of the "City Mills." The bottom of the river at this point is limestone. The dam has an extent across the stream of 160 feet. Its face is composed of masonry, with the addition of a mud-sill and cap-sill, the whole corresponding almost precisely with the face of the dam already



STONE AND TIMBER DAM.

described, except that there are no upright posts connecting the upper and lower sills.

The mud-sills, which cross the stream, are 12 by 14 inches, being of the same size as those in the other dam. The first mnd-sill, at the face of the dam, is laid on the rock, which is leveled off as smoothly as possible to receive it; and 40 feet up-stream from this is placed another 12 by 14 inch sill, parallel with it, the two being bound together with timbers 6 by 8 inches, running lengthwise of the stream, and placed at intervals of 12 feet for the whole width of the stream. Around the first mud-sill a stone wall is laid in water-lime, and on the foundation composed of this wall and sill the face of the dam is built, consisting of solid masonry, 30 inches in thickness. On the top of this wall is placed the 12 by 14 inch cap-sill. This cap-sill or plate is kept in its place by means of binders 6 by 8 inches, which extend from the plate to the up-stream mud-sill. These binders are fastened to the timbers which tie the two mud-sills together (as already described) by iron rods, and are also supported by posts to give them the necessary stability. Furthermore, across these binders, which run lengthwise of the stream, smaller timbers, 4 by 6 inches, are framed, parallel with the face of the dam, to keep the binders from spreading apart.

All the timber work in this dam is dovetailed where cross-timbers are met; and in fastening the framework together, ten kegs of 8-inch spikes were used, from which it will be seen that it is not likely to become separated by any strain it is liable to undergo.

Back of the face of the dam a layer of clay was filled in, clear up to the face of the cap-sill; back of this, brush, rubble stone and gravel were put in; and on top of this was spread a coat of clay. A covering of two inch planks was then put on, the whole length of the dam, for a distance of 20 feet from the crest toward the up-stream extremity, next to the face of the dam. Finally, a covering of gravel was spread over the entire up-stream slope, with the exception of about six feet along the cap-sill.

The banks of the stream are faced with a wall of masonry, connecting with each end of the dam and forming the abutments. There is certainly no lack of strength and solidity in the dam, and its manner of construction and selection of material appear to be, for the region in which it is located, of a very judicious character. If we were to take any exception whatever, it would relate to the use of clay as one of the materials for filling, our own experience and observation having convinced us that it is less reliable for this purpose than any other substance used, whether it be gravel, loam, sand or brush. Undoubtedly, in the case here described, the other sources of strength and compactness in the structure of the dam will preclude any danger of injurious results from the presence of the clay; and when thus protected by better material, it may answer as well as any to a limited extent; but in cases where it is expected to resist of itself the inroads of the water, we should not regard its use as safe or profitable.

CHAPTER XXXII.

DAM FOR QUICKSAND BOTTOM.

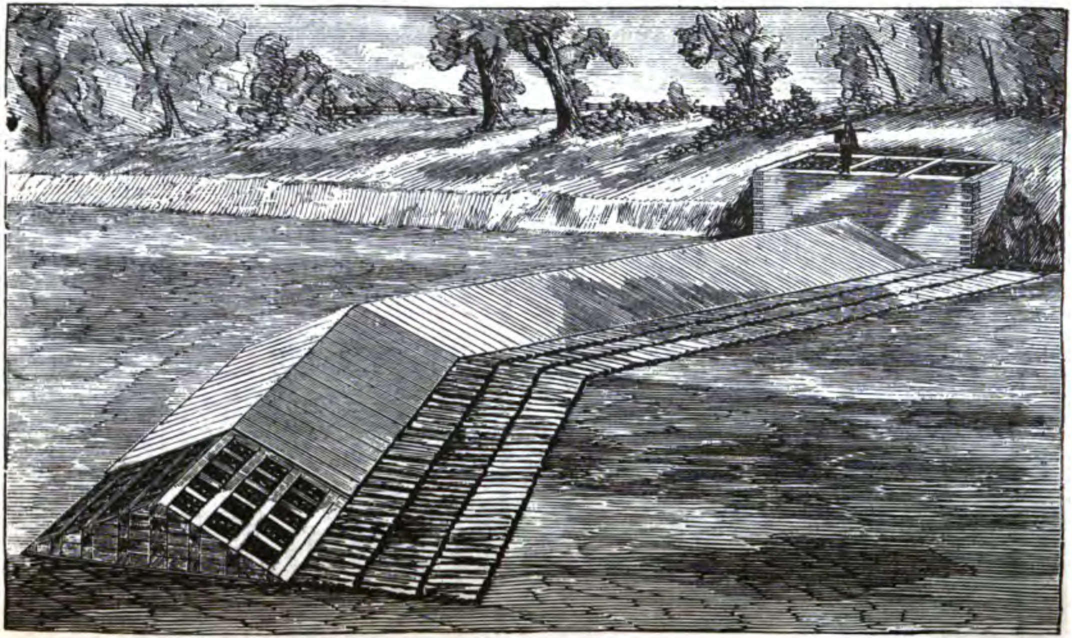
In the issue of Leffel's Mechanical News for November, 1873, appeared the following inquiry from a Kansas correspondent, over the initials "D. P.": "How can a dam be put in with 10 feet of sand or quicksand at the bottom?" In this inquiry is presented one of the most formidable difficulties with which the builder of a dam has to contend. We will not pause to discuss on abstract grounds the principles which should be followed in a case of this nature, but proceed at once to describe a dam in the erection of which the obstacles referred to were encountered, and which has shown by its permanence that it possesses all the necessary elements of durability.

Our engraving gives a general view of the dam to which we allude, viz.: the "Hydraulic Dam" across the Tippecanoe River at Monticello, Indiana, which was built in the year 1849, under the direction of Mr. E. A. Magee, for the Hydraulic Co., of that place.

This dam rests upon a quicksand foundation, and the banks of the stream on each side are also of sand. The length of the dam between the abutments is 340 feet, its width from up-stream to down-stream extremity (exclusive of the apron in front) is 24 feet, and its height 5½ feet. The abutments, only one of which is shown in the engraving, are each 30 feet long, 12 feet high and 12 feet wide, and are composed of timber and rock as hereafter described. The foundation of the dam, part of which constitutes the apron, is laid as follows: commencing with the down-stream tier of the apron, the lower extremity of which is 18 feet from the down-stream edge of the main portion of the dam, poles or small trees from six to eight inches in diameter at the butt and from 40 to 50 feet in length, with all the brush left on at their upper ends, are laid lengthwise of the stream as close together as possible, and rock enough placed on them to hold them to their position. A second tier of the same kind is then laid, the ends of the trees being six feet back of those in the first tier; and a third tier follows in like manner falling back from the second tier six feet as before.

Six feet up-stream from the ends or butts of this last tier of trees is commenced the base of the dam itself, which is thus already provided with a secure foundation, composed of the upper portions of the three tiers. As the entire distance from the up-stream extremity of the 24 ft. dam to the down-stream edge of the 18 ft. apron is but 42 feet, and as the trees in the three foundation tiers are 40 to 50 feet long, their upper portions will of course extend under the whole base of the dam. The weight of the dam serves to hold them securely in place, and they in turn give the dam a hold upon the bed of the stream of such breadth and strength that it is practically immovable.

For the first course at the base of the main dam, seven sills or stringers are laid, cross-wise of the stream, the one farthest down stream



DAM FOR QUICKSAND BOTTOM.—MONTICELLO, INDIANA.

being, as stated, six feet from the ends of the uppermost tier of trees in the apron. The ends of these sills are seen in our engraving. They are 14 by 16 inches in size, and their distance apart, between centers, is 4 feet, dividing the width of the whole base into 6 equal parts. They are lapped on each other where two ends meet, and fastened together with 2-inch pins. Their upper sides are counter-hewed to receive the cross-timbers, which are put in at intervals of 10 feet for the whole length of the dam. These cross-timbers, whose direction is of course lengthwise of the stream, are 12 inches square, and those in the first course are 24 feet long, being equal to the width of the base of the dam. They are counter-hewed and let down evenly on top of the first course of stringers or sills.

The second course of stringers, which are five in number, are 12 inches square, and counter-hewed on top like the first or bottom course, upon which they rest solidly, making, with the cross-timbers, a "water-joint." Next comes the second course of cross-timbers, 12 inches square and counter-hewed, but shorter than the preceding course, the width of the dam being less as it approaches the top; then the third, fourth and fifth courses of cross-timbers, all of which are 12 inches square, and counter-hewed, so as to form the "water-joint" by their contact wherever they cross. The fifth or last of the courses of stringers consists of a single timber 12 inches square, laid solidly on the center tier as shown in the engraving. The outsides of the outer stringers, and the ends of the cross-timbers, are beveled so as to present a smooth and even-inclined face, which is planked on both the up-stream and down-stream slopes of the dam, as shown in the cut. The planks used are 2½ inches thick, and are fastened to the timbers with 6-inch spikes.

By the crossing of the sills and transverse timbers in the frame, with water-joints as above described, a large number of cribs are formed; and these are filled with rock up to the comb of the dam.

The abutments, the dimensions of which have already been stated, are composed of timbers 12 inches square, counter-hewed and laid solidly one upon the other. They are lapped at the ends and pinned with 2-inch pins. Through the interior of the crib thus formed extend two courses of ties as shown in the cut, dividing it into three smaller cribs, all of which are filled with rock to the top. Outside of the abutment, both up and down the stream, for a distance of three feet, the bank is excavated, and the sand thus taken out is replaced with fine gravel and clay and sand puddle. On the side and end next to the water above the dam, sheet piling is driven, and the abutment is planked up and down with 2-inch planks. On the upper side of the dam and on the brush of the tree-tops projecting above, a coating of gravel two or three feet thick is placed.

It will be observed that this dam by its construction forms an angle across the river, with the point or vertex up stream, thus giving it to some extent the elements of strength pertaining to the arch, but requiring less care in the framing than if a regular curve was made

across the stream. It should be here stated that the engraving is in some respects an imperfect one, as it does not show the planking on the abutment; and in the cross section of the dam in the front of the picture, the shape and arrangement of the counter-hewed sills and cross-timbers are not accurately represented. The cut is, however, sufficiently correct to enable the reader, aided by the minute description we have given, to form a clear idea of the manner in which the work is done.

In building this dam, 15,000 feet of hewed timber, 26,000 feet of plank, and 1,575 poles or trees were used. The total cost at that time (1849) was about $4,500, but would be greater now, as labor and materials are both more costly than 32 years ago. The durability of the structure, with its broad base and the pyramidal form of the main dam, are sufficiently manifest, the strength of the abutments and the weight of the filling both in abutments and in the cribs of the dam, being such as to give abundant stability, in spite of the unfavorable nature of the river bed. For a period of 15 years it required no repairs; but afterward the abutments above the water were rebuilt, and some repairs were afterward made on the dam itself.

CHAPTER XXXIII.

OVERHUNG APRON DAMS.

Dams of several different kinds, adapted to streams having a hard bottom, have been illustrated and described in preceding chapters of this work; and as the one of which we now propose to speak does not differ greatly from some already shown as regards the material used and the general principle of construction, we have given only an outline sectional view of it, which will, however, present with sufficient clearness all the novel features contained in it. The apron, in fact, is the only point in which there is any radical departure from the system laid down in former chapters. In this respect, the dam here shown is quite peculiar; but as it has stood the test of practical service for a number of years, we must conclude that for the locality and the kind of foundation upon which it is built, it is a reliable structure, at least under any but the most extraordinary circumstances.

This dam was built in 1867, Mr. C. Goodnow, of East Sullivan, N. H., with other parties, performing or superintending the work. Its height is 13 feet, and its length about 60 feet across the bed of the stream, at the point where the foundation timbers lie; while, measuring on the cap or top of the dam, the distance is 80 feet. One end of the dam rests against a ledge, while at the other end is a steep gravel bank.

In the cut (Fig 1) A A represent the foundation sills extending

across the stream, which consist of whole trunks of trees, some 24 inches in diameter at the butt. These sills are made flat on their upper surface to receive the cross-sills B, which are 12 inches square and locked on the top of the sills A, as shown in the cut, the gains being 2 inches in depth. The spaces between the sills are filled with rocks. The rafters C are 28 feet in length, 12 inches in diameter at the lower end, and 10 inches at the upper end. They are notched upon the up-stream sill A, and at the other end upon the cap timber F. The posts D are 10 inches in diameter, with a 3-inch tenon at each end, one being inserted in the cap timber F, and the other in the cross sill B, which runs lengthwise of the stream and resting on the foundation

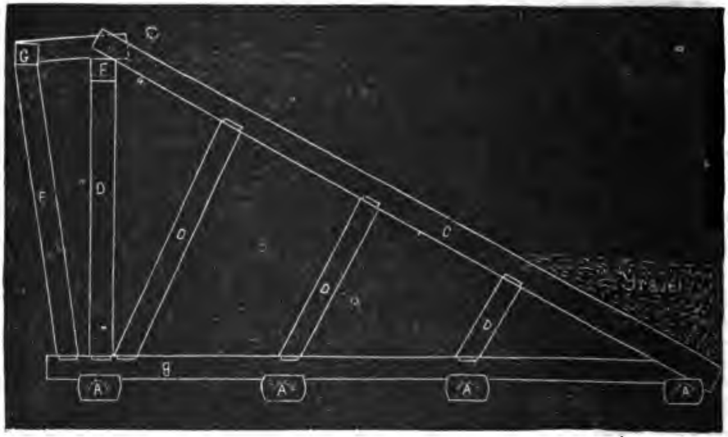


FIG. 1.

sills A. The length of the posts D is sufficient to give the dam, at the crest, a height of 13 feet, as already stated. The distance between the rafters is 4 feet, from center to center.

The manner in which the apron is framed is plainly indicated, and will attract the particular attention of the reader. The sills B project down stream beyond the front foundation sill A far enough to receive the posts E, which incline somewhat down stream from the front of the dam. At the upper end of the posts E they are framed into the cap timber G, from which short timbers extend to the top of the cap F, meeting there the upper ends of the rafters. The projection thus formed, which we have called the apron, (although it bears but little resemblance to that portion of the dams hitherto described) serves to carry off the water from the dam, the overflow in floods being frequently 20 to 30 inches deep on the crest. Of course on any other than a rock

or very hard gravel bottom, an apron of the usual kind, and of considerable extent down stream from the base of the dam, would be required to prevent washing and undermining; but there appears to have been no necessity for it in this case.

It should be further stated that the rafters of this dam are covered with planks 2½ inches thick, which are secured to the rafters with 5-inch spikes. The total amount of lumber used in building the dam was 25,000 feet.

Another dam, strongly resembling this in its method of construction and in the kind of apron attached, but of a still simpler form in many respects, is in use at Millbrook, Dutchess county, New York. We give

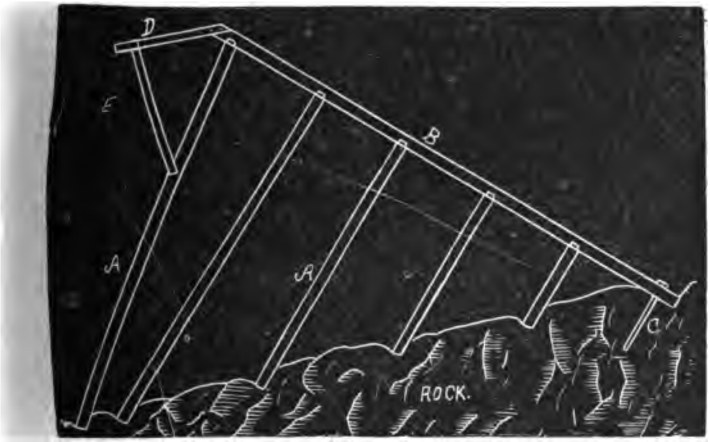


Fig. 2.

in Fig. 2 a representation of the manner in which it is built, from which it will be seen that nothing more simple or economical in the way of frame-work can well be devised. The particulars in regard to this dam are furnished to us by Mr. V. Anson of Millbrook, who states that the stream on which it is built has a rock bottom and sides, the river bed being quite steeply inclined, as indicated in the cut. No mud sills are laid, and no timbers are required to rest the braces or studs A A upon, as they are footed directly into steps or notches in the rock. The distance between these studs is 5 or 6 feet, or whatever space may be adapted to the height it is desired to give the dam. In framing the studs into the rafter B, the builder of this dam states that he found it much better not to make long tenons, secured with pins, as the timber would give out in and around the tenons. He therefore made them quite short, just enough in fact to keep them

firmly in their places, and omitted the pins; and the results were entirely satisfactory.

The studs A and the rafter B constitute (aside from the apron) one bent of the dam; and these bents are placed side by side in a direct line across the stream, with intervals of 2 or 3 feet between them. Having been set perfectly plumb and properly stayed, they are covered with planks, 2-inch pine being considered sufficient for this purpose.

At the foot of each rafter, up-stream, an iron rod C, 1¼ inches in diameter and 2 feet long, passes through the rafter and into the rock for a considerable distance. It is manifest from the position of the rafter and direction of the rod that the pressure of the water from above the dam will tend to keep the rod in its place rather than to withdraw or loosen it; and it will have a like effect to preserve the foothold of the studs in the notches cut for them in the rock bottom.

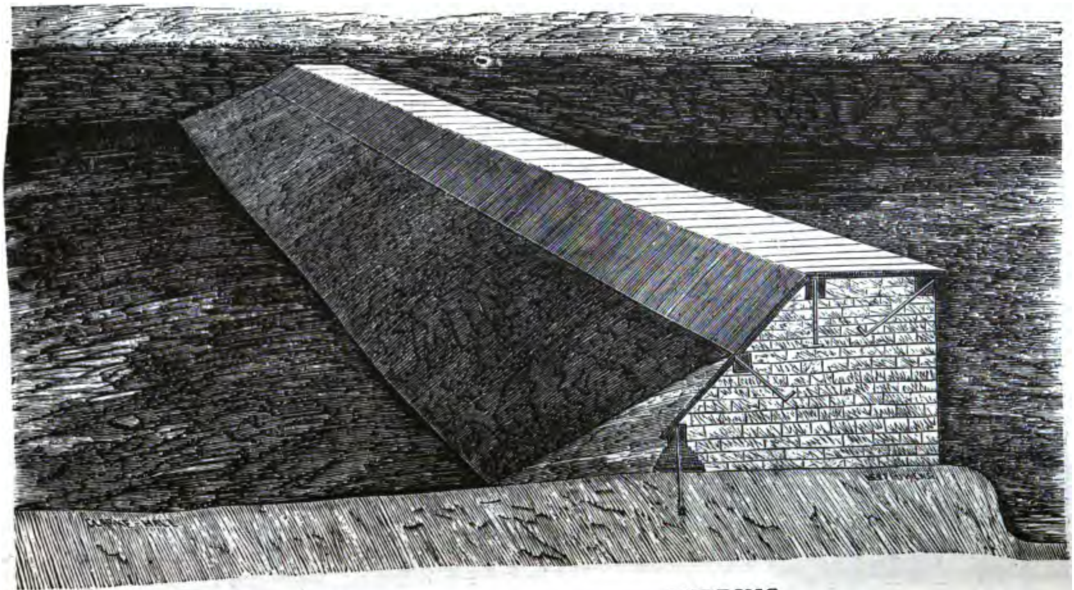
The cut shows very clearly the construction of the apron, the timber D having a slight incline from the horizontal, and being halved on to the end of the rafter and secured by pins or otherwise; while near its outer extremity it is supported by the brace E. One end of this brace is tenoned into the timber D and the other into the stud A, as shown. It will be observed that the stud A at the front of the dam is not parallel with the others, but is drawn in at the foot—the object being to avoid the fall of water from the apron upon the foot of the studs, which would in time loosen them and weaken the entire structure.

The studs and rafters are 12 inches square, and the timbers of which the apron is made 4 or 5 inches square. It is unnecessary to remark that while this form of dam may be entirely reliable on a rock bottom, with banks of the same character, and other circumstances of a favorable description, it would be impossible to give it the requisite strength and firmness, on the majority of streams, without mud sills, and also an apron at the front of the foundation, such as we have illustrated in former chapters.

CHAPTER XXXIV.

STONE DAM WITH PLANK COVERING.

It will be perceived on a very superficial examination of the dam illustrated in the present chapter that it is of an extremely substantial nature, and presents no weak point in any part of its structure to lead to a destructive inroad of the current. The plan of the particular dam shown in our engraving is taken from drawings furnished us by Messrs. Fassett & Stevens, of Lewiston, Maine; this dam having been built on the Sabbatus River at Lisbon, Maine, for Hon. N. W. Farwell. The same parties have built a number of dams of the same general description, it being adapted to any locality where the river has a ledge bottom and sides, and in such cases has never failed to give entire



STONE DAM WITH PLANK COVERING.

satisfaction. For any other sort of bottom or banks it would of course be unsuitable, without very material modifications, and the addition of abutments, apron, etc., none of which are here required.

The dam here referred to is about 150 feet long and 10 feet high. The body of the structure, as will be seen, is simply a solid wall of masonry, of the height above stated, about 14 feet broad at the base, perpendicular on the down-stream face, and sloping on the up-stream side to a breadth of some six feet at the top. Resting on solid rock, it requires no foundation sills; but a bed-sill or timber is provided to receive the lower ends of the planking, and other timbers are placed at suitable points, as shown, for attachment of the planking in a perfectly secure manner. All these timbers run across the stream, lengthwise of the dam for its whole extent. The bed-sill first mentioned is 12 by 12 inches in size, and is placed, not directly upon the ledge, but at an elevation of about two feet, resting on an intervening foundation of brick built in pyramidal form as regards its cross-section, and laid in hydraulic cement. The purpose of this is to give the bed-sill a perfectly water-tight footing, as there might otherwise be a possibility of leakage beneath it which would loosen the timber in its position and consequently impair the security of the planking, The bed-stick is secured to the ledge by means of pins of round iron, 1¼ inches in diameter, and of sufficient length to enter the ledge, below the brick-work, at least 15 inches. These pins are placed at intervals of not over five feet between their centers, requiring in all 30 pins for the whole length of the timber. They are well driven, and wedged at the lower end to prevent any liability to work loose. The manner in which this is done is indicated in the engraving, and has also been mentioned in a previous chapter; the end of the pin being split five or six inches up and an iron wedge inserted, which, when the pin is driven down, comes in contact with the rock and is thus forced up, spreading, the point of the pin and giving it such a hold as to prevent the possibility of its withdrawal. The introduction afterward of fine wet sand will give the desired firmness to the pin, and is recommended for this purpose as equal to lead or cement.

The other timbers are of the same size as the bed-sill, 12 by 12 inches, and run in the same direction. The manner in which they are secured in the stone-work is plainly shown in the illustration, pins of the same material and size being used as on the bed-stick, but with the ends turned at a right angle, it being impracticable to wedge them as in the other case. The timber at the front of the dam is square, while the other two, as will be seen, are beveled in such a way as to adapt them to the planking. The planks of which the covering consists are 3½ inches in thickness, and laid as indicated in the cut.

The stone for such a dam as is here described may be taken from any ledge of field stone. About one foot of the thickness of the dam, on the face or down-stream side, should be laid in cement mortar, to ensure its durability and tightness.

The shores being each a solid ledge, no abutments are required, it

being only necessary to make the connection of the dam with the ledge perfectly tight by means of the cement and filling. The filling, on the up-stream side, may be of dirt, sand and gravel, its only purpose being to exclude the water from the base of the dam.

The apron of this dam, it will be observed, is a natural one, the front of the wall being within two or three feet of the edge of a steep ledge about four feet in height, extending across the stream.

Hon. N. W. Farwell, for whom, as above stated, this dam was built, is the proprietor of very extensive cotton mills, and is using several of the larger sizes of the Leffel Double Turbine water wheel.

CHAPTER XXXV.

TIMBER DAM AT SOUTH HADLEY FALLS, MASS.

One of the largest dams ever built in the United States is that which extends across the Connecticut river at South Hadley Falls, 8 miles north of Springfield, Massachusetts. It was completed in October, 1849, the work having been prosecuted by the Hadley Falls Company, incorporated for this purpose in 1848 with a capital of $4,000,000.

This dam is 1,017 feet long, and 28 to 32 feet in height, and is built of timber, with the exception of the interior filling and the abutments, the latter being of solid masonry. Before laying the timbers, the river-bed, which is of solid rock, was excavated to a depth of 4 feet, and a width up and down-stream of 90 feet, being equal to the base of the dam. The first sill was then laid, 12 by 12 inches in size, extending across the stream, and bolted down to the bed-rock with two-inch iron bolts. Rafters of the same size were then placed lengthwise of the stream, two feet apart, extending from the sill to the rock bottom, and sloping up-stream, their ends being scarfed to fit the bottom, and secured with two-inch iron bolts at both ends. Timbers were then laid cross-wise of the rafters, two feet apart, followed by another set of rafters, and so on until the desired height was reached. The work was protected while in progress by a coffer-dam. The size of the timbers throughout was 12 by 12 inches, and all were fastened with 2-inch bolts as already described.

The spaces between the timbers were filled in with stone for fifteen feet from the bottom, and gravel was laid over this and in front. The slope from the top of the dam to the upper edge of the base is 21½ degrees. The covering consisted of six-inch planks, bolted to the timbers, the ridge being double planked; and at the points where it was most exposed to damage by ice it was further protected by a covering of boiler-plate iron. About 4,000,000 feet of timber was required for the construction of this dam, in addition to the large quantity of stone for the abutments, as well as for the filling at the foundation and between the timbers.

The piers, as already stated, are of solid masonry, but the strain upon them is in fact much less than might at first sight be supposed, as the dam, which is built straight across the stream, is so constructed as to be practically self-supporting. It has in fact withstood the heaviest freshets ever known in the Connecticut river. A striking proof of its reliability was afforded in the great October flood which occurred some years since, when the stream pouring over the dam measured in depth, on the cap of the dam, twelve feet, three inches.

When the dam was built, the rock bottom was deemed sufficient to protect the structure from being undermined by the overfall. At a later date, however, the rock under the dam was found to be undermined by the action of the water (when impeded by ice that had gone over the dam and piled up in the stream below) so that the whole fabric was in danger of sinking. About one million feet of lumber and stone was required to fill the excavation made by the water, and build an apron sloping from the top of the dam down-stream, its total extent being about three hundred feet.

The water is admitted by 13 gates to a main canal faced with masonry, 140 feet wide at bottom, 144 feet at the top, and 22 feet deep, branching at a distance of one-fifth of a mile from the river into two mill-races, for the use of factories on different levels. The water from the upper race, after moving the mills on its proper level, is conveyed back to a point near the river, where it falls into the lower race. The motive power afforded by this dam is believed to be without a superior in this country. It is utilized in the propulsion of extensive cotton-mills, paper-mills, &c., the products of which reach a formidable yearly aggregate, and represent the labor of several thousand men. The dimensions of the dam, and the volume of water which is thus made available for manufacturing purposes may be judged from the fact that the roar of the fall is sometimes heard for a distance of 40 miles; and at Springfield, which is eight miles distant, doors and windows are frequently observed to rattle in unison with the vibrations produced by the overfall at the dam, and of course more distinctly perceptible in its immediate vicinity. The occurrence of these vibrations has afforded an interesting subject of study to scientific men, it being found that they vary with the varying temperature of the atmosphere, increasing in number as the temperature rises. When the thermometer indicated 70 deg. Fahrenheit, the vibrations were 130 per minute; at 80 deg., they rose to 137 per minute. The observations of which this report is made were taken by Prof. Snell, of Amherst College. The general subject of vibrations of this character has also been investigated and discussed by Prof. Loomis, who states that the vibrations have in some cases been so marked and continuous as to be a source of extreme annoyance to persons living in the vicinity; and it will readily be comprehended that the monotony of such an effect, when indefinitely prolonged, would become almost intolerable to people of very nervous and sensitive organizations. It appears from a number of instances on record that the vibrations do not occur, or at least do not exhibit the

regularity otherwise attending them, unless the water falls in an unbroken sheet; and they have been interrupted or altogether stopped by a floating log catching on the top of the dam, or by strips of wood attached to the crest of the dam expressly for the purpose. The question whether the air or the earth is the medium of transmission of the vibrations is an unsettled one, although the powerful influence of the temperature of the air upon their frequency would seem to favor the theory that they are principally conveyed by that agency. It is quite possible, however, that both the air and the ground, (especially if there are extensive intervening ledges of rock, affording a continuous transmitting medium,) may share in this instrumentality.

We are indebted for many interesting facts relative to the dam above described, to Mr. M. H. Arnold, of West Stockbridge, Mass.

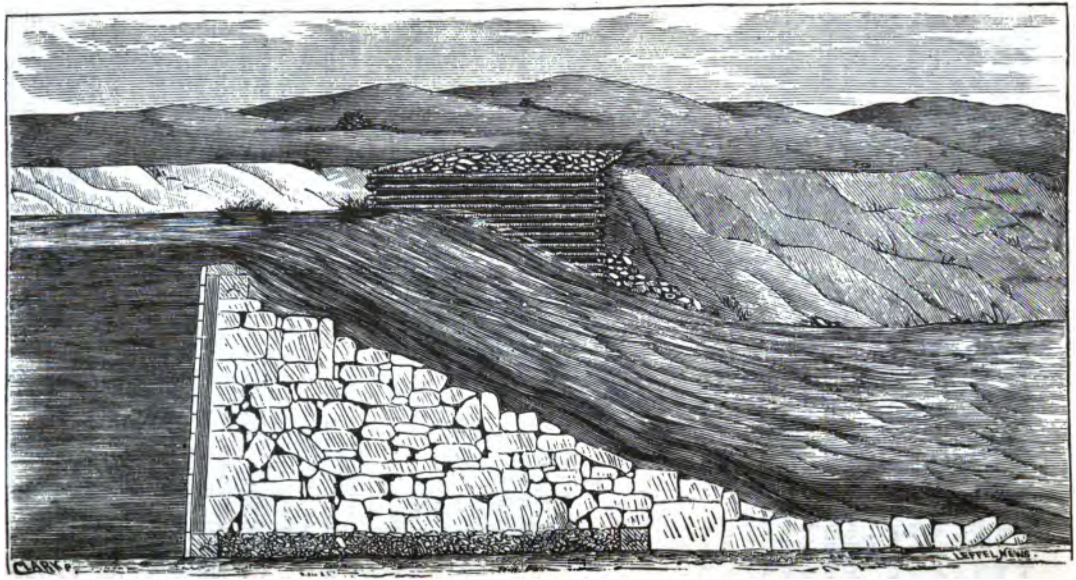
CHAPTER XXXVI.

STONE APRON DAM.

In the dam which we illustrate in this chapter, the usual order of construction appears to have been reversed, and what would at first glance be taken for the up-stream is in reality the down-stream slope; while the perpendicular side of the dam, instead of being at the front, with an apron at its foot, is at the back of the dam, the whole remaining part of the structure serving in the capacity of an apron, and carrying off the water in a gradual fall or rapid. But notwithstanding this reversal of the method ordinarily adopted, the dam here shown is believed to possess great durability, and for the locality in which it was built is said to be extremely cheap. An examination of the cut is sufficient to convince the practical reader that provided the river-bed be of a character enabling it to withstand the effects of the current, the dam itself has ample power of resistance.

Our engraving presents a cross section of the dam, and one of the crib abutments. The builder is Mr. A. Garnsey, of Sanford, Maine, who states that the stream has a hard gravelly bottom—not a ledge—and that rough stone, which it will be seen is the material chiefly used, is abundant in the vicinity. The length of the dam, across the stream, is 130 feet, and the extreme height 10 feet, from the bottom of the up-stream mud-sill to the top of the cap-timber forming the crest of the dam.

In beginning the work of construction, the bed of the stream was dug down to the "hard-pan," and the two mud-sills were laid (the ends of which are shown in the cut) cross-wise of the stream, their size being 12 by 12 inches, and the distance between them 15 feet. Between these sills small stones were filled in, to a level with the top of the sills, as shown in the engraving; and upon the foundation consisting of the



STONE APRON DAM.

sills and stone filling the wall of which the dam is composed was laid. The kind of stone employed, and the manner in which it was laid, are so plainly shown as to require no explanation. Upon the up-stream mud-sill are erected the posts, against the upper and nearly perpendicular face of the dam (which requires to be as smooth and even as practicable) these posts being 6 by 6 inches, and placed at intervals of 2 feet. Upon the summit of the wall, and with its upper surface flush with the top of the posts, is a cap timber corresponding with the mud-sills, and of the same size, 12 by 12 inches.

To the upright posts the planking is secured, extending horizontally across the stream, 2-inch planks being used, and laid snugly together. Planks are also nailed, as will be seen, to the up-stream mud-sill, making them continuous from the base to the crest of the dam. Finally, a cap piece consisting of a very thick plank is pinned or spiked on the top of the posts and the cap-timber previously mentioned, its upper surface being flush with the top of the planking, and the water being thus carried over the comb of the dam without tending to displace the 12-inch timber.

The special object of the builder of the dam in adopting this plan was, as stated by him, to avoid the expense of constructing an apron of timber, stone being very cheap and abundant. He suggests the laying of stones below the mud-sill on the down-stream side, taking care to place them together in such a manner that the water will not roll them out of place; and he adds that the further they are extended down-stream, the better. This feature is illustrated in the engraving, in which it will be seen that the base of the dam is continued down-stream for a considerable distance, large rocks being used, set squarely together, and so firm in their position that the current will pass over without disturbing them.

If the bed of the stream is clay, or of a sandy nature, spiling should be driven down, against the upper side of the up-stream mud-sill; but the river bottom, in the case of the dam here shown, was too hard to admit of spiling being put in, even were it desirable.

The abutments, one of which is shown in our illustration, are cribs of the usual description, logs being laid up and the interior filled with small stones, with which other suitable materials may be mixed, to make a compact mass and prevent leakage, as described in former chapters.

CHAPTER XXXVII.

PILE AND FRAME DAM.

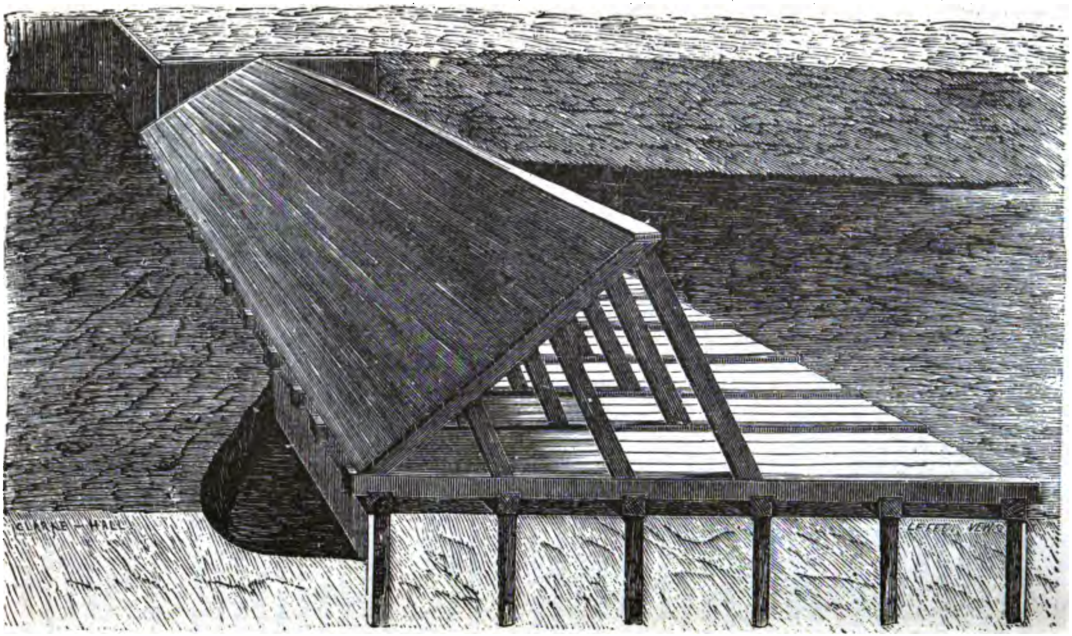
The description and illustration given in this chapter, like those in Chapter XXXII, were elicited by the inquiry signed "D. P." in Leffel's

Mechanical News for November, 1873, "how to put in a dam with ten feet of quicksand at the bottom." The dam here shown was built some years since in Mobile County, Alabama, by Mr. Andrew McGregor, afterward Superintendent of Vaughan's Mills at Moss Point, Miss., who states that the stream on which it is located has a quicksand bottom of eight to twelve feet depth. The average depth of water in the river was two feet, the width being 68 feet, and the power afforded, with 10 feet 2 inches head, was applied in driving two 56-inch saws, each cutting an average of 15,000 feet of lumber per day.

The first step in the construction of the dam was to turn the stream with a bay-dam of brush and dirt. A trench was then cut in each bank 16 feet long and 4 feet wide, down to the water-level of the river. Six rows of round piling were then driven, extending across the stream, the piles consisting of pine poles 18 feet long and 10 inches in diameter. The piles in each row were placed 5 feet apart from center to center, and the distance between the rows, up and down stream, was 6 feet from center to center. In the first or up-stream row there were 20 piles, making the total length of this row about 95 feet, extending at each end about 12 feet into the trench, above mentioned. The other five rows each comprised 14 piles, forming, when all were driven, a crib or pen about 68 feet long and 30 feet wide, up and down stream. The front row of 20 piles, it should be further stated, was continued at each end, an addition being made at right angles with the dam, and extending 12 feet up the stream, along the bank, thus forming a rectangular wing at each extremity of the dam.

Tenons were then cut on the head of each pile, down to the water level, and cap-sills framed on each row across the stream, the sills being timbers 12 by 12 inches square. Upon the cap-sills were gained stream-sills consisting of timbers 10 by 12 inches, which were let in 4 inches on the cap-sills. On the front row a filling was then put in, between the stream-sills, of pieces of timber 8 by 12 inches, and 4 feet 2 inches long, making a level surface on this row. Flat piles 3 by 12 inches, 18 feet long, were then driven on the up-stream side of the front row of round piles, making close joints, and extending, as already stated, a distance of about 95 feet across the stream and into the trench at each bank. This flat piling was spiked fast to the cap-sill, and cut off on a level with the top of it. Flat piling, 2 by 12 inches and 18 feet long, was also driven along each side row of round piles, and across the lower end, or down-stream row of piles, thus completely enclosing the crib or pen formed by the round piling as above stated. The corners were made secure by driving the piling double at those points and lapping joints. The surface of the crib was filled in or floored with sheeting 2 by 12 inches, nailed fast to the mud-sills and the joints made as tight as possible, to prevent any chance of washing by water running over the dam.

The rafters consist of timbers 15 feet long, and 10 by 12 inches square, framed upon each stream-sill, the foot of the rafter standing 4 inches back from the face line of the front mud-sill, so that the bottom



PILE AND FRAME DAM.

plank on the face of the dam can be beveled to a tight joint on the stream-sills and the filling of short 8 by 12 timbers between them. The rafters have 10 feet 2 inches rise, that being the perpendicular height of the dam from the stream-sills to the crest. Each rafter is provided with three braces of 10 by 12 timber, mortised into the stream-sill with 3 by 12 inch tenons. The rafters and braces are framed with a view to throwing the strain downward and backward, as will be apparent on an inspection of the engraving.

The face of the dam is constructed as follows: for the lower portion, reaching one-third of the way up, five rows of planks 3 inches thick and one foot wide were put on, the lower plank being beveled at its bottom edge to a tight joint with the stream-sills and filling as already specified; then five courses of 2-inch planks, same width, and with close joints; and for the last or upper third of the face, five courses of 1½-inch planks, the upper three courses being laid without nailing, so that they could be taken off in case of high water. The 3-inch planks of the first five courses were fastened with 6-inch spikes; the 2-inch planks with 4-inch spikes, and the first two courses of 1½-inch planks with twelve-penny nails.

Against the face of the dam a filling was put in of sand and clay, extending up the slope a distance of five feet. This filling is not shown in the illustration, being omitted in order to present more clearly the construction of the dam itself.

The manner in which the wings or abutments of the dam are built requires more specific explanation. The front row of piling, as already stated, is so extended as to form a wing at each end of the dam, projecting 12 feet into the bank and turning 12 feet up-stream; and cap-sills were framed on top of these piles in the same manner as the others. In each wing were then placed five posts, 11 feet long, of 10 by 12 timber, framed on the cap-sills, making the abutment wings 12 feet high. Flat piling 2 by 12 inches and 22 feet long was then driven down, 10 feet into the ground, and spiked to the cap-sills, 24 piles being required for each wing. A filling of sand and clay was then put in and packed close. When thus finished the wings are not seen, and in order to show them the filling is omitted in the engraving. The object in turning the wings up-stream is to prevent the possibility of the water working its way around the abutments. A similar arrangement, it will be observed, protects the bank at the end of the dam from being washed out.

Mr. McGregor states in regard to the preliminary part of the work:

"It requires both skill and patience to get piling through quicksand. I used two 600 lb. hammers, and derricks 26 feet high, raised by two mules with snatch-blocks and tackle. Bolted on the derrick in front I had two strong bars of iron; the first, one foot above the sill, and the other six feet above, to form guides for piling. After placing a pile I worked it back and forth to settle and line it; then made it secure, and let the driver fall four or five feet, letting the hammer rest on the pile for about one minute, and shaking gently after each fall. By this

means I got each pile home, *settling* them through the sand rather than driving, and making a perfect job much quicker than trying to force them through by hard driving. I have followed millwrighting for twenty years, and speak from experience."

As the mill-foundation accompanying this dam is of somewhat peculiar construction, we give a brief abstract of Mr. McGregor's account of the manner in which it was built. It is, in fact, simply a down-stream continuation of the foundation of the dam. Nine rows of round piles were driven, 5 feet apart across the stream, and 10 feet apart up and down the stream, the first row being 10 feet from the lower end of the crib or dam. Tenons were cut on the head of each pile, and mud-sills mortised on, thus constituting an addition of 90 feet to the foundation-crib of the dam. Timbers extending 90 feet, and 10 by 12 inches in size, were then framed on the 4th, 8th and 12th stream-sills of the dam, continuing those sills down-stream and making their total length 126 feet, the width of the addition, cross-wise of the stream, being 38 feet from out to out. This foundation was floored with 2 by 12-inch plank, nailed to the mud-sills. Posts were mortised and framed in, 10 feet apart, 14 feet between joints, for 110 feet, or up to the head of the rafters of the dam. Two posts were then framed on the face of the 4th, 8th and 12th rafters, and stringers put on, 126 feet long, making the mill floor 36 feet wide in the clear and 126 feet long. The dam being 68 feet in length across the stream, and the mill 38 feet from out to out, a space was left, it will be seen, of 15 feet on each side of the mill. This space was occupied by the water wheels, which were of the description known as "breast wheels"—one on each side of the mill, 15 feet wide and 13 feet 6 inches in diameter, and giving 20 feet distance from the head of dam to face of wheel. The flumes were 15 feet wide, 20 feet long, and 2 feet deep, and built in the following manner: On each side of the mill, two of the top-boards on the face of the dam were cut off, flush with the mill posts and the abutment posts. Three posts were framed in on each of the outside stream-sills. The posts next the wheels were 10 by 18 inches, and cut out to a radius of 13 feet 10 inches, so as to admit 1¼ inch flooring, nailed on to form a shroud, to increase the length of time for which the water is retained in the buckets of the wheel. The outsides of the flumes were nailed to three short posts set for that purpose, and the inner sides to the posts of the mill.

The builder of this dam and mill structure found that by the plan above described a very material saving was made in cost of frame; and he also asserts that the work was much firmer than if the two were separately built—the frame adding strength to the dam and foundation, making it as solid as a rock for the mill.

In our present engraving, as in many preceding ones, the dam is shown as if cut in two lengthwise of the stream, giving a cross-section of the structure, and exhibiting nearly every part very clearly; the river-bed being also shown as if dug out against a part of the up-stream face of the dam, in order to show the position of the flat-piling with

which that side is protected, the upper part of the piling only being visible.

CHAPTER XXXVIII.

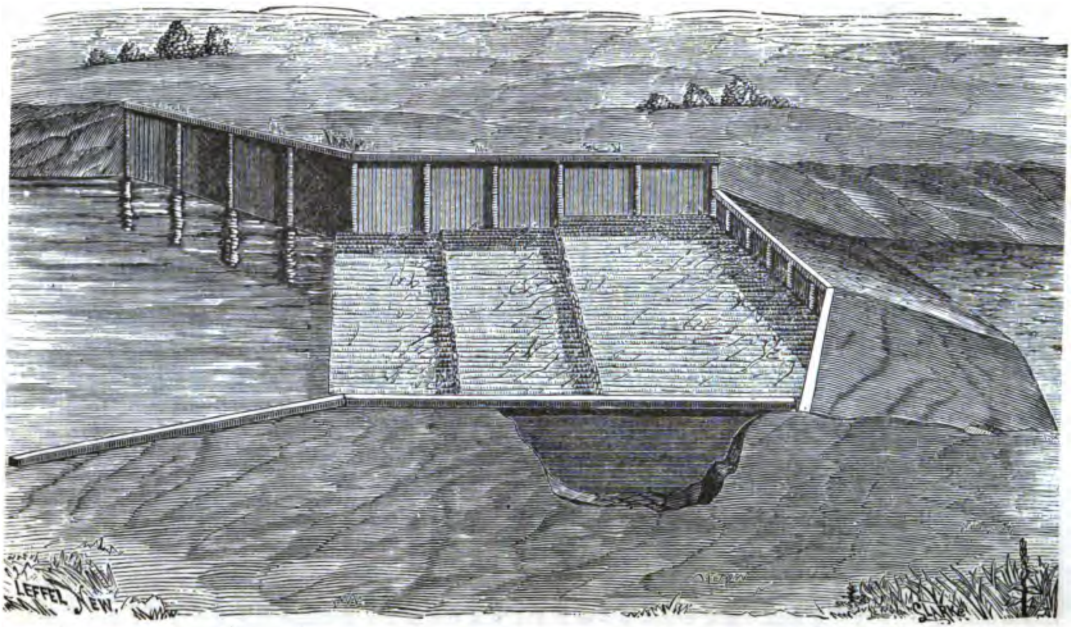
PILE AND BRUSH DAM.

In the present chapter we describe a dam which, though embodying principles of construction that have already appeared in different combinations in preceding chapters, constitutes as a whole an arrangement of materials sufficiently novel to justify a somewhat minute account. The dam here illustrated is located at Mormontown, Taylor County, Iowa, and was built in the summer of 1871, by Messrs. Thos. King & Co. The stream on which it is situated is a small one, being but about 60 feet wide, with a sandy bottom and sand or clay banks. The nearest point at which stone can be obtained in sufficient quantity to build a dam is 15 miles distant; and as the cost of such material, delivered at the spot, would have been too great for the economy it was desired to practice, resort was had to other methods of construction. Two or three dams had been washed out (in what manner they were built we are not informed) at the point where this one now stands; but this, so far as we have learned, has withstood all the floods which have occurred, and has shown no signs of giving way. Brush and prairie sod were the substitute adopted in place of stone; not as being a preferable material, but on acount of the inconvenience of obtaining the latter.

In beginning the work, piles were driven in a row across the river, two feet apart, the row making an angle instead of a direct line, the middle being some six feet farther up the stream than the ends at the banks. A row of piles was also driven along each bank, extending down the stream for sixty feet and turning outward at the lower end. The piles used were mostly of burr oak, about 12 inches in diameter, trimmed and sharpened and driven top in the ground, and squared at the top or upper end for tenoning as hereafter described. Short piles, sawed 6 inches wide throughout, and 2½ inches thick at one end, tapering to ¾ inch thick at the other end, were then driven all around on the inside of the main piling. Above the sawed piles or sheeting, planks were put on, 2 inches in thickness, and the main piling thus sided up.

Along the entire length of the piling, as will be seen in the engraving, both at the banks and across the stream, a cap-timber is put on. This timber is 8 by 8 inches, and to receive it a tenon 3 by 8 inches is made on the top of each of the piles.

Outside of the piling, and between it and the banks, below the dam, a filling of prairie sod was put in, this with the piling itself forming the abutment.



PILE AND BRUSH DAM.

In constructing the dam, or what might be called the apron, the first step requisite was to lay the lower course of the three shown in the illustration. The work was therefore begun, at a point below the lower piles in the stream, by laying small trees or saplings, without trimming, placing them lengthwise, with the tops up-stream, and as thickly as appeared necessary to render them compact and substantial, the layer extending from bank to bank. This having been completed, a second layer was put on, six or eight feet farther up-stream; and this was succeeded by a third layer, falling back six or eight feet as before, and carrying the work so far up-stream that the extremities of the saplings reached above the piles driven across the strram. The brush was worked between the piles, and on their up-stream side the filling was put in to the height intended for the dam, 8½ feet. For this filling, brush and prairie sod were used, sloping up-stream as shown.

The piles along the banks, forming the abutments of the dam, are some five feet higher than those in the dam itself, the effect of this elevation of the abutments being that when the water is high enough to run over them, there is no fall over the dam, but a comparatively level flow, and consequently no danger of washing below the abutments. The piles in this dam are driven into the sand from 12 to 15 feet. The water is admitted into the race at a point some 30 feet above the dam.

It will be seen that comparatively little material of an expensive character is used in the construction of this dam, and that a great part of the work could be done without the employment of skilled labor, the framing of the cap-timber on the piles being the chief exception. The manner in which this dam was built renders it difficult to give a precise statement of its cost, Messrs. King & Co. doing most of the work themselves, with their own teams, and employing such assistance as was necessary by the day or month; to which they add, "we also had some help from our neighbors." They, however, estimate that the dam would cost, if all the material were to be bought and the labor hired on the usual terms, perhaps $2,000. Messrs. King & Co. are using a James Leffel water wheel to drive their grist-mill, and state that its performance exceeds their expectations.

It should be here remarked that by an inadvertence the planking on the further side of the stream, secured to the piles on their bank side, is made to appear in the cut as if put on up and down; whereas it should be in a horizontal position, as shown on the nearer bank, where the earth is represented as if dug away in order to give a view of the planking.

CHAPTER XXXIX.

LOG AND PLANK DAM.

As regards cheapness of construction, with at the same time all needful elements of durability and strength, a very satisfactory result was reached in the case of the dam illustrated in the present chapter; but it is also to be observed that the circumstances were highly favorable to economy, the cost of a large part of the material being absolutely nothing, aside from the expense of transportation; and this was not a formidable item, as everything required was procurable in the immediate vicinity. This dam was built in Lycoming county, Pennsylvania, in 1848, and has therefore seen sufficient service to entitle the plan of its construction to considerable confidence. The stream at this point has a gravel bottom; the west bank is sand and the east bank a sandy loam, and their average height is about 4 feet above the water line on the up-stream side of the dam. The total length of the dam is 75 feet, and its height, from the down-stream water line to comb of dam, 8 feet. Round timbers are used throughout (with the exception of parts of the abutments, as hereafter specified), and the planking is hemlock joists 3 inches thick.

For the foundation, five sills were first laid across the stream, their diameter being about 15 inches. Upon these, eight sills were laid, lengthwise of the stream, of the same size as the foundation sills; and between these stream-sills shorter timbers were placed, parallel with them, laid snugly together, and with their down-stream ends flush with those of the stream-sills, but extending up-stream only as far as the center log of the dam, which rests on the stream-sills and runs across the stream. The ends ot this center-log, and of three similar logs in a vertical line above it, are conspicuously shown in the cut. The purpose of the builder in allowing these timbers, intermediate between the stream-sills, to extend only to the center of the dam, instead of running them quite through to the up-stream mud-sill, was to let the interior filling, in the up-stream half of the dam, rest on the gravel bottom of the river; while below the center log, or in the down-stream half of the dam, the filling rests on the stream-sills and the shorter timbers lying compactly between them, giving weight and a corresponding degree of stability to the dam. Furthermore, the projection of the stream-sills and the short timbers in front of the dam, constitutes, as will be seen in the engraving, a very substantial apron, so that the water, after coming over the slope of the dam itself, strikes these projecting timbers and runs off smoothly, avoiding any reaction or the formation of a bar below the dam.

The length of the eight stream-sills is 25 feet, and of the projection in front of the dam about six feet. The short timbers between the stream-sills, to reach to the center of the dam, must therefore be about 15 feet long. They are put down as solidly as possible and "spotted" upon the foundation-sills on which they rest.

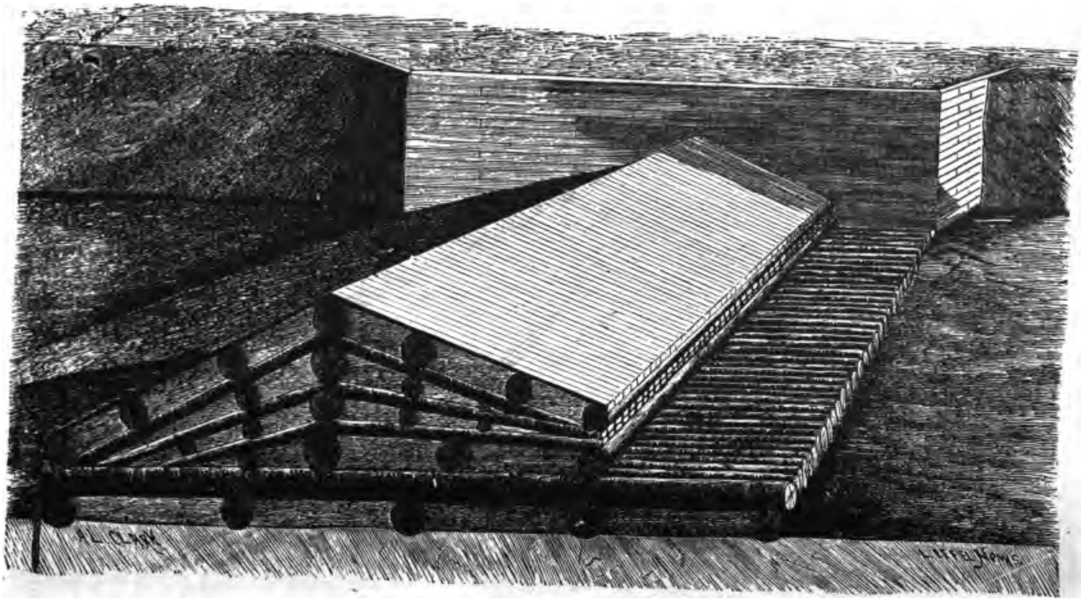
The next step was to lay the first and lowest of the four center-logs, already mentioned. For this purpose a timber as large as could be conveniently obtained was employed, 15 inches or more in diameter, the object being to give the dam as rapid an elevation as possible, a less number of ties being thus required. Other timbers of somewhat smaller size were laid parallel with it, as shown, and round ties or rafters placed on them, the upper end of each resting on the center log, to which they were notched and pinned, the lower end of the down-stream rafter pinned to the log resting on the stream-sills, and that of the up-stream rafter to the up-stream mud-sill. This end of the up-stream tie is therefore not seen in the illustration, being concealed by the stream-sill behind which it passes.

Another center log was then put on, directly above the first, and ties notched and pinned on in the same manner as before, their lower ends being secured to the same timbers as the ties already laid. Then came a third center log, and a third tier of rafters or ties, notched and pinned and their lower ends resting respectively on the upper cross-sill at the down-stream face of the dam, and on the foundation-sill at the up-stream side. Between the successive tiers of rafters small timbers are introduced, parallel with the center logs and cross-sills, as shown in the engraving, their purpose being to give the rafters a solid bearing.

Finally, the fourth or topmost of the center logs was put on, and on each slope of the dam three bearers parallel with it, and of about the same size, were laid as shown in the cut. These bearers were hewed on one side to receive the covering, both slopes of the dam being sheeted with 3-inch hemlock planks.

The whole interior of the dam was filled with stone and gravel; and on the up-stream side, from the bed of the stream up to the foot of the planking, a depth of about three feet, a filling was put in of round creek gravel, slate gravel being added on top of this until the entire filling extended about half way up the slope of the dam. We have indicated in our engraving a course of flat or sheet piling at the foot of the up-stream slope, although the builder of this dam informs us that no piling was used. We think it would be advantageous to introduce foot-piling against the up-stream mud-sill in the manner we have shown, securing it to the sill, as in this way the water would be prevented from working under the dam, in case the gravel filling should not entirely exclude it. The builder of this dam considers it best to extend the planking no farther down the slope, on the up-stream side, than the top of the sill or bearer resting on the stream-sill. By this method more space is given for the gravel filling than if the planking extended down to the river-bed, and he is of opinion that the gravel, having access to the mud and stream-sills, will effectually close the leaks and will in due time settle into a compact and impervious mass. If the planking is to run to the bed of the stream, he advises the digging of a puddle ditch or trench to render the foot of this slope perfectly secure against leakage.

One end of this dam abuts against the foundation of the mill; at the other end, which is the one shown in the engraving, is an abutment of



LOG AND PLANK DAM.

the usual description. This is built of timbers hewed on three sides, and put up with the ties dove-tailed into the front timbers and notched into the back timbers. The ties and the back timbers are round. The face timbers of the abutment are 25 feet long, being equal to the width of the dam, and are notched, at the base of the abutment, upon the ends of the foundation-sills of the dam. At the ends of the abutment, the ties, hewed on three sides, are run into the bank at an obtuse instead of a right angle, the ties of the down-stream wing being about 12 feet and those of the up-stream wing 10 feet long. The interior of the abutment is filled with gravel and stone. Its height is 6 feet above the crest of the dam, or 14 feet from the water line below the dam to the top of the abutment.

The heaviest of the timbers used in building the dam were generally, as already stated, about 15 inches in diameter, the lowest of the center logs being still larger than this. The ties or rafters running from the center up and down stream to the mud and cross sills were not more than 10 inches in diameter, on an average.

The bank on the side of the stream on which the abutment is located is not quite so high as represented in the engraving, being about two feet below the top of the abutment, or four feet higher than the water line on up-stream side of dam.

The cost of this dam, as stated by the builder himself, will be considered extremely moderate. He says: "I put this dam up in 1848 for $153. I hired labor for $1.00 per day, and teams for $2.50, and filled the whole with stone up to the planking. The stone was handy; had to haul it but a short distance.

The plank cost, delivered, $5.00 per thousand feet, making	$ 28 00
Total labor and hauling,	125 00
Total cost,	$153 00

The timber was rough hemlock, cut on our own land, and we did not consider it worth anything. When timber is plenty, I consider this as cheap and durable a dam as can be built."

It will be seen that the expense of constructing such a dam at the present time, or under circumstances less favorable as regards cheapness of materials and convenience of obtaining them, would be considerably greater than indicated by the foregoing figures. This fact should be borne in mind in estimating the cost of any similar structure; but the full description we have given will enable any one interested to judge of the comparative cost of the work in a different locality and in a time of higher prices than were in vogue 33 years ago.

The mill for which this dam furnishes the motive power is situated, as above-mentioned, on the shore of the stream opposite to the abutment, the flume being directly between the mill-house and the dam, and a wing of the mill building extending out over the head-race. As the tail-race is carried along the side of the stream and in close proximity to the current, the builder says: "I run a small crib from the dam down the creek, built of small round timbers, averaging from 8 to

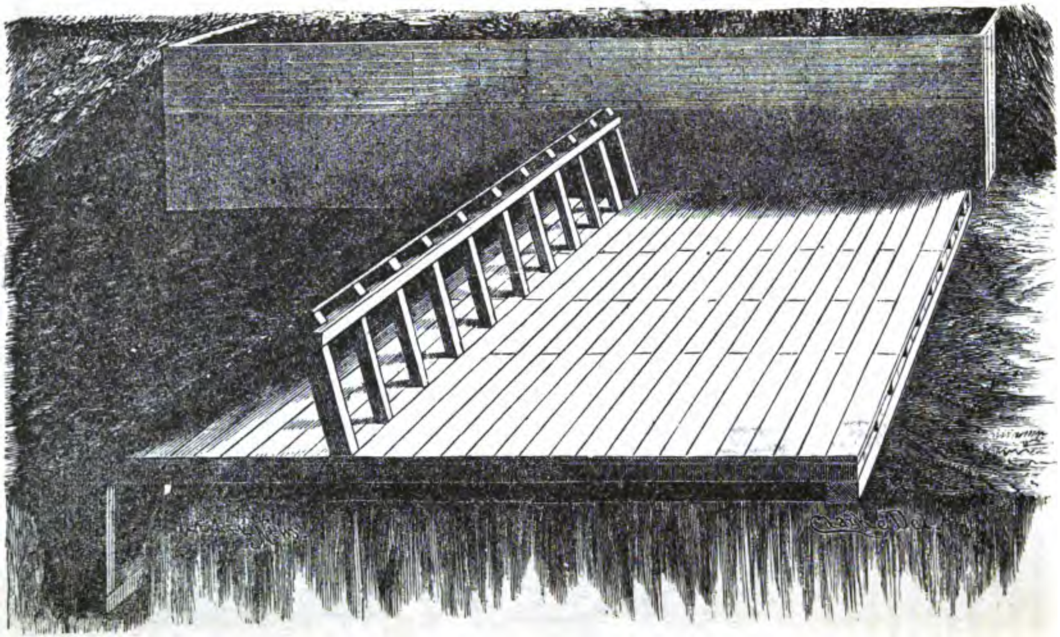
10 inches in diameter. The crib was 6 feet wide and about 4 feet high, and was filled with stone. The object was to keep the water, after it passed over the dam, from entering the tail-race. I started below the dam and sunk the tailrace down to gain head, making about 18 inches by that method."

CHAPTER XL.

FRAME DAM WITH SHEET PILING.

Upon either a mud, sand or gravel bottom, the description of dam presented in this chapter will be found, it is believed, a satisfactory one in all respects; and although not so economical in cost as some which have been previously illustrated, it still does not compare unfavorably with other plans, for the locality in which it was built. The best evidence of its merits is the fact that it has proved to be reliable where other methods of construction had signally failed. Preliminary to building this dam (which is situated 2½ miles from Pittsburg Landing, Hardin county, Tennessee), a temporary dam of brush and dirt was thrown up to turn the water from the spot where the work was to be carried on. A ditch was then cut extending across the stream, from bank to bank, a distance of about forty feet. A mud sill 12 inches square was laid at the bottom of this ditch for its whole length, and in this sill mortices were cut at intervals of 4 to 6 feet to receive the posts. The posts are 12 inches square and cut to a length equal to the head of water it is intended the dam shall afford, which is in this case 4 feet. This is the rule adopted by the builder of this dam, his theory being that the pressure to be resisted by this part of the structure is the same, and requires the same length of timbers, as in the case of the superstructure. He, however, expresses the opinion that for a much higher head the length of the posts in the ditch need not be proportionately increased, and that, for example, posts 10 feet long would be sufficient if the dam were to give 15 or 20 feet head. In our own view, posts of much less length would answer equally well, as the lateral or sidewise pressure of earth is a very different thing from that of water. It need hardly be remarked that the depth of the ditch, the digging of which is the first item in the work, will be determined by the length it is intended to make the posts—the top of the post, when set, to be about one foot below the ordinary level of water in the stream.

The posts having been framed into the mud-sill, a cap-sill is put on top of them, reaching the whole length of the dam. A double row of sheet piling is then nailed on the up-stream side of the frame composed of the mud and cap sills and the connecting posts, the two courses of piling being so placed as to break joints. The piling may



FRAME DAM WITH SHEET PILING.

be of any suitable thickness, but should all be of the same width, in order that it may be snugly put on, one row covering the joints of the other. Another sill, 12 inches square and 40 feet long, is then laid across the stream, on the river bed, at a point 20 feet down stream from the cap-sill on the posts. Stream-sills or sleepers of about the same size, and 20 feet long, are put on, their up-stream ends fitted to the cap-sill, and their other ends to the parallel down-stream sill. The stream-sills may be placed 3 feet apart. The ends which connect with the cap-sill are halved with it so that the stream-sills rest on the post and the cap-sill is let in upon the stream-sill, as shown in the engraving. At its lower end, the stream-sill is laid on top of the cross-sill, and spiked or pinned to it. The flooring is then put down, for which purpose 2-inch planks may be used. In our illustration the flooring is shown running cross-wise of the stream; but if sleepers were laid across the stream-sills, the planks for the floor could then be put on lengthwise of the stream, which we think the preferable method.

Upon the platform thus constructed, 40 feet across by 20 feet up and down the stream, the posts, rafters and covering of the dam are placed. The posts are 12-inch timbers, of sufficient length to give the dam a perpendicular height of 4 feet, and are set on the floor, the foot of each post being directly over a stream-sill, and firmly spiked down. Upon the top of this line of posts a 12-inch cap-timber is framed, and from this cap-timber the rafters, equal in number to the posts, extend to the up-stream edge of the floor, where their lower ends are secured with 12-inch spikes. For the slope here given to the dam, the rafters would require to be about 8 feet long. A shoulder is cut on the upper end of each to fit them to the cap-timber; and the rafters are then covered in the same manner as the apron or floor already described.

For the abutment, a ditch should be dug, and a mud-sill, posts and cap-sill put in, on the same plan as above indicated for the dam, with the same protection of sheet piling, in a double row, on the water side of the posts. A wall of hewed logs is then laid up, 40 feet long, its lower end being even with the down-stream extremity of the dam, and its upper end 20 feet up stream from the ditch at the base of the dam. At each end, the abutment is turned at a right angle and carried back into the bank; and timbers may also be built-up in the rear and ties inserted connecting the face and back of the abutment, forming a strong crib of the same general description as those represented in former chapters. The interior of this crib should be filled with earth, gravel or rock. The height of the abutment here shown is about 8 feet; and it should, in any given case, be carried up far enough to be a little above the highest stage of head water, to prevent the stream from washing over or breaking around and injuring the banks. The cracks between the logs are stopped with planks to prevent leakage into the crib. In the engraving, planking is shown put on vertically, extending up to a level with the crest of the dam; and if the whole face of the abutment is covered in like manner, it will be all the more secure. Hewed logs are preferred to other lumber for erecting this

abutment, as being more durable and equally satisfactory in other respects.

The chief peculiarity of this dam, and one which seems to recommend it for any suitable locality, is the manner in which the sheet piling at the base of the abutments is secured, being fastened to sills at both the top and bottom of the piles, instead of driven down into the river bed in the ordinary manner. Mr. John H. Macdonald, of Pyburn's Bluff, Tennessee, who erected this dam in 1867, describes his previous experience in the use of piling as follows: "In 1866 I built this mill, and drove the spiling to a depth of 5 feet. I thought I had one of the best jobs in the world, and it was nice at the top. In June, 1867, my dam undermined, and everybody cried out 'Rat!' On examining it carefully, I found that it was the fault of the spiling, and when I ditched it out I found it in this shape: Stick your three fingers out straight—then draw your second finger forward—you can then see how my spiling was at the lower end. Now I suppose this is the case with all drove spiling; and no wonder the rats get so much abuse. Suppose a rat cuts a hole in the drove spiling, and the water commences running through; there is nothing at the lower end to hold, and the spiling begins to give way, one by one, till all is gone or ruined. The advantage my plan has over spiling is this: suppose a rat does cut a hole through the spiling, all the water can do is to pour through the hole. It cannot affect the dam, for the spiling is fast at the bottom and top. It must move the whole of the dam and mill and abutment at the same time. I feel assured that parties who build their dam and abutments in the manner I have described will save money in the long run, and the rats will go in peace."

Mr. Macdonald also states that at the point where he built this dam, four mill seats had been undermined and ruined and three owners broken up; but the dam here described has now been standing (in 1874) seven years and is still sound. It is our impression that the flooring or apron planks of Mr. Macdonald's dam run lengthwise of the stream instead of across it, resting on sleepers transverse to the stream-sills as suggested in the foregoing article; but our engraving was made from data in which the transverse sleepers were not included, and the flooring was therefore represented resting directly on the stream-sills and cross-wise of the river.

CHAPTER XLI.

DOUBLE CRIB DAM—TRESTLE DAM.

A method of constructing a dam which may interest our readers by the somewhat novel features it possesses, is presented by a structure of this kind on the Dakota or James river, in Dakota Territory, erected

by Mr. D. Shearer. The bed of the river is a mixture of clay and sand, and is not very solid. The banks are of clay, quite firm and reliable, 14 feet high on one side, while on the other side is a bluff some 75 feet high. The distance between them is about 100 feet. The dam consists of what may be called a double crib, with an intermediate filling, an up-stream filling or slope, and a double apron of stone on the down-stream side.

In the first place, a log crib was built, straight across the stream, 8 or 9 feet high, and of sufficient width to give it the necessary stability, say 8 feet. This crib was filled with rock and clay, and 12 or 14 feet farther up stream another crib was built, similar to it but only 4 feet high, and of proportionate width. Stringers or ties were put in, extending between the cribs and holding them firmly together, and the space between them was filled with rock and clay. Above the up-stream crib, also, a filling was put in of the same materials, these being close at hand and costing little or nothing.

The apron is terraced, so to speak, consisting in other words of two long steps, giving it the form of the log aprons illustrated in previous chapters, where the successive courses of logs fall back as they rise, giving the water a gradual descent. The apron in this case is built of rock, the part next to the front or down-stream crib of the dam being 4 feet high and extending down stream 14 feet. Below this is the second apron or step, also of rock, 2 feet high where it joins the first apron, and extending 12 feet down stream, sloping at the same time to a height of only 1 foot at its lower extremity. This gives a total extent of apron, lengthwise of the stream, of 26 feet, and the water is thus very smoothly and gradually carried away. The entire width of the base, from the up-stream extremity of the filling above the upper crib to the down-stream extremity of the stone apron, is about 60 feet, while the length across the stream, as above-mentioned, is 100 feet. With so broad a base, relatively to the height, the latter being only 8 or 9 feet at the highest point, or surface of the down-stream crib, it will be seen that even with a strong current and a large volume of water, the dam is not likely to be carried off. The use of clay in the filling is the only feature which leads to any apprehension of injury by water working its way through; but the distance it must penetrate to do any material damage, and the use of rock in connection with it, render any disaster of a serious nature highly improbable. If a moderate proportion of sand or loam were also employed, so that any small inroad or gap which the water might produce would be speedily closed by the settling together of the materials themselves, there would be still less liability of trouble from this source.

The canal or race to convey the water to the mill is to be commenced at a point 10 or 12 rods above the dam. We should here remark that although we have in the foregoing account spoken of this dam as a structure actually completed and in service, it was in fact only in contemplation at the time our data concerning it were obtained; but we believe it has been built substantially upon the plan above described.

TRESTLE DAM.

For a locality in which it is intended to obtain but a comparatively low head, say not above 3 or 4 feet, a dam of very simple and cheap construction may be built, resembling somewhat the frame dams described in preceding articles, but of much less weight of timber and expense of framing. For a dam 3 feet high, trestles may be made of round timbers 6 or 7 inches in diameter and from 9 to 10 feet long, these constituting, with their covering of boards, the slope or upper surface of the dam. Near the upper end of each of these rafters three supports or legs are inserted, close together at the point where they enter the rafter, but spreading below in a direction parallel with the stream, thus giving them the requisite firmness against longitudinal pressure. The holes for insertion of the legs may be made with a 2-inch auger. The trestles thus constructed are set about 3 feet apart, with the legs down stream, and the up-stream ends of the rafters settled thoroughly into the gravel or mud; or if the bottom is rock, the ends of the rafters should be beveled so as to fit upon it snugly. The trestles are set in a straight line across the stream, the rafters being in an even range so as to receive the covering in a regular and uniform manner. For the covering, inch boards are sufficient, secured to the rafters with nails. In putting them on, the work should be commenced at the top and continued toward the bottom of the slope. If the stream is a large one, a second course of boards may be put on, nailed on top of the first. This second course will run up and down, parallel with the rafters and the direction of the stream, the first course being necessarily laid crosswise of the stream. A filling of gravel, or of small stones, sand and loam is now put on the upper surface of the dam, and the work is finished. The strength of the fabric may be still further increased if it is underpinned with rock, and flat stones placed, broad side down, in front of the legs supporting the trestles. When thus strengthened, it is claimed that no liability of settling exists, and that the dam is absolutely secure from being washed out.

Mr. John F. Hazzen. of Sonestown, Pennsylvania, who furnishes us with particulars in regard to this dam, pronounces it, on the strength of his own experience, a cheap and good one. He states that he has used a dam of this kind at his mill for over twenty years. He also put in one of similar construction, five miles farther down on the same stream. This dam was but 20 inches high, and no difficulty was ever experienced with it. It resisted all the floods that ever passed over it, and when removed had to be torn out. The river has what is called a "rolling bottom," composed of gravel and sand, and is said to be a very hard stream on which to hold a large dam in place, in case of the water washing under it and the dam consequently settling or tending to float off bodily.

CHAPTER XLII.

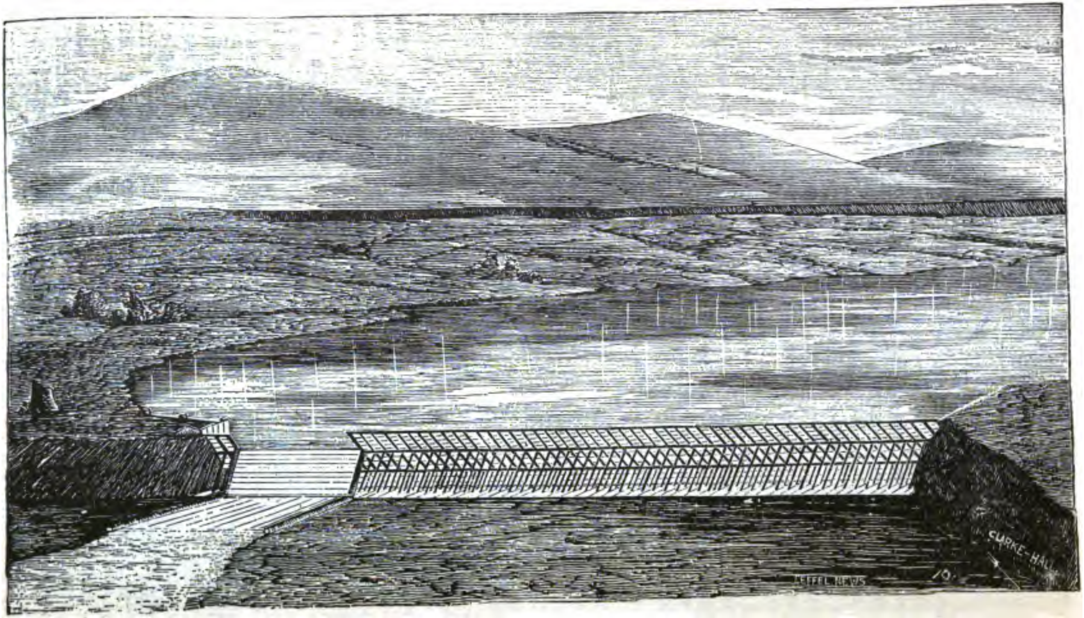
LIGHT FRAME DAM.

The actual length of the dam illustrated herewith is 264 feet, and including the planking of the abutments, amounts to about 300 feet; but in order not to reduce the scale of the engraving so low as to prevent the construction from being distinctly shown, the length of dam, as represented in the cut, is but about 100 feet, its height to the water line being 7 or 8 feet. It is situated in Stephentown, Rensselaer county, New York, and was built by Mr. Eugene C. Goodrich in 1872, to run a circular saw and planing mill. The stream is a small and fluctuating one, and has a bottom of clay, gravel and mud. The object of the builder was to construct a tight dam, entirely of wood, to form a reservoir. The area of the reservoir thus obtained is about eight acres.

The foundation consists of three rows of large elm logs or mud-sills, laid crosswise of the stream, about 4 feet apart, each log from 12 to 24 feet long, as convenient; the logs of each row breaking joints with those of the next row. These are laid in trenches frcm 2 to 3 feet deep. Across these mud-sills are laid the cross-sills, lengthwise of the stream, 12 feet long, 9 inches square, and placed 6 feet apart. These sills are notched 1½ inch on the bottom, where they cross the three mud-sills, and pinned with 1½ inch pins. The mud-sills are spotted from 3 to 6 inches deep, and faced on the up-stream side. The cross-sills are also notched 1¼ inches deep on the top, a little up-stream from directly over each mud-sill, to receive the foot of the posts and the lower plate.

The posts, or braces, of which there are two courses, are 6 by 7 inches, the wide way being put lengthwise of the dam, and are pinned at the foot with 1¼ inch pins, without tenoning. There are three plates running lengthwise of the dam and supporting the rafters, each plate consisting of pieces 12 feet long, put in to break joints. The lower plate is 8 inches square, and rests directly on the cross-sills at the up-stream foot of the dam, in the 1¼ inch notches before-mentioned. The middle plate is 7 inches square, and rests on the short posts, which are about 3 feet long, a 1½ inch tenon being made on the upper end to hold the plate on, and a ¾ inch pin put in. The upper plate is 6 inches square, resting on the long posts, which are about 6 feet in length, and framed and pinned in the same manner as the short posts. The distance between the lower and middle plates is about 3½ feet, and between the middle and upper plates 4 feet. The posts are set at a right angle with the rafters, and at an angle of a little less than 45 degrees with the cross-sills. Braces 4 by 5 inches square are also put in between the middle and lower plates, over the cross-sills.

The rafters are 4 by 5 inches, and 3 feet apart between centers, every alternate one being over a post and cross-sill, and pinned with 1-inch pins. In the general view of the dam in our engraving, only



LIGHT FRAME DAM.

half the rafters are shown, those occurring between the posts being omitted. The lower ends of the alternate rafters mentioned, which are those shown in our engraving, are notched over the up-stream ends of the cross-sills, and pinned so as to bind all firmly together. The frame-work is all red oak. The planking is chestnut, 2 inches thick for about two-thirds of the height from the bottom, and 1½ inch thick for the other third. Every plank is grooved, and tongues of oak ½ by 1¼ inch put in. This the builder considers a very important item in a tight dam. The planking in the abutment is also tongued, and even the spiling at the bottom. The planks are only 6 feet long, and are thoroughly pinned with ¾-inch oak pins.

At the up-stream ends of the cross-sills there are short oak posts driven down in the ground (of the same size as the rafters, 4 by 5 inches) and pinned at their upper ends to the cross-sills, to which are spiked 2-inch planks 12 feet long. To these the upper ends of the spiles are spiked, the planks also forming a tight joint at the angle between the spiling and planking. The spiles are of 1½-inch chestnut plank, tongued—though any kind of wood will answer, as being entirely under water at all times, it will last an indefinite period. The spiles are 4 feet long, more or less, according to the kind of bottom in which they are driven, and are sharpened on the flat sides and driven tight together. This is a slow and tedious process, but is of vital importance.

The ends or abutments are formed by perpendicular posts and planking, even with the foot of the dam, similar to the rafters and planking of the main dam, extending 12 feet into the bank at the west end and 24 feet at the east end. Below, or on the down-stream side of this upright part, there is a solid bank of dirt and brush filled in, about as high as the water line, some 10 feet thick, and very firm and compact. There is also a filling of mud, dirt and gravel on the water side of the abutment, and along the whole length of the dam, extending about 3 feet up the planking.

The apron is 60 feet long, and, as will be seen in the illustration, its upper edge is even with the upper plate of the dam. There are at present no flash-boards, but is the intention of the owner to put them on the coming season. The apron is planked directly on the main posts of the dam, (which are supported by braces between the middle and upper plates) with 2-inch planks, so that the water will slide instead of falling over it. At the bottom are 12-feet planks 3 inches thick, placed lengthwise of the stream on two long mud-sills, their upper ends resting on the third or down-stream mud-sill of the main dam, and pinned with 1-inch pins. At the foot of the posts, across the 3-inch planks, is a 2½-inch oak plank to receive the force of the descending water and the shock of flood-wood coming over the apron. One-tenth of the capacity of the apron will carry the stream at an ordinary stage but it sometimes rises very rapidly and to a great height.

No spiling is considered necessary at the lower end of the apron.

In addition to the general view, we give a smaller cut showing a cross-section of the dam, in which the parts above described will be readily identified.

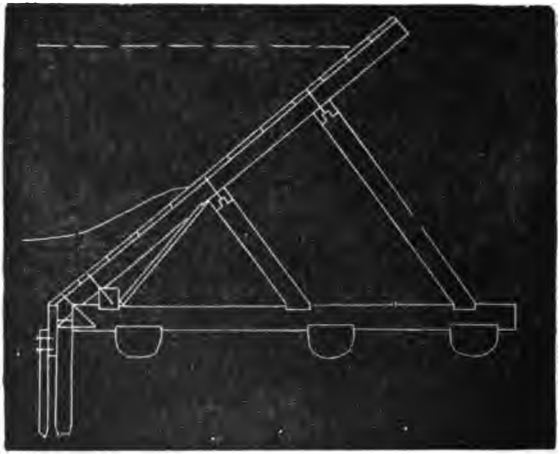


FIG. 2.

About 22,000 feet of lumber was used in the construction of this dam, valued at $550, and the cost of labor was about $950, making the total cost of the dam $1,500. The builder is confident that a cheaper dam of the length and size could not well be made, light timbers being used throughout.

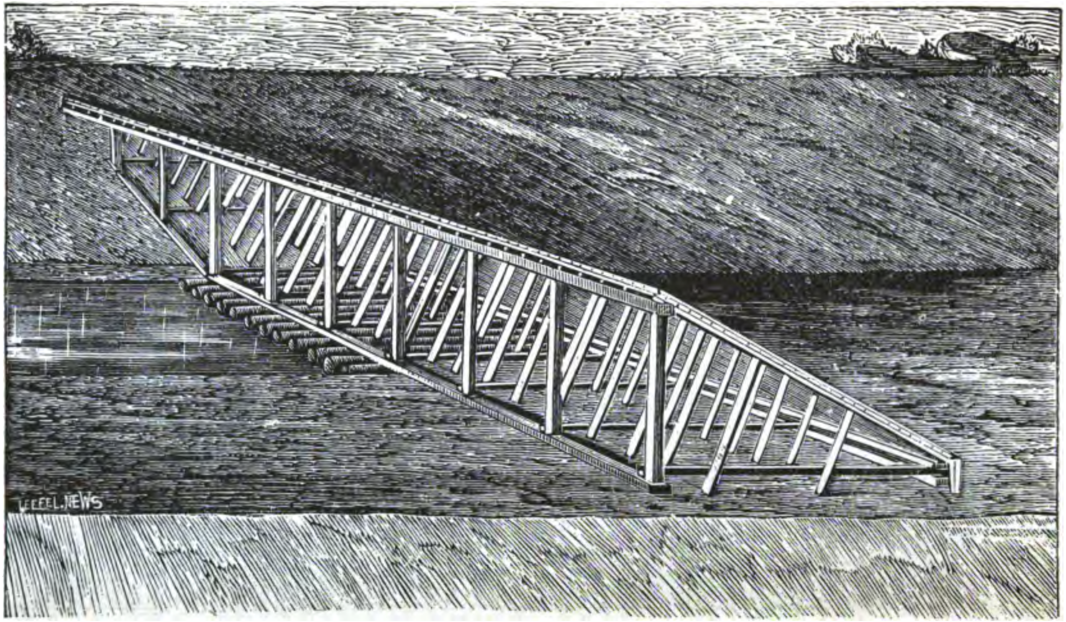
The stream on which this dam is built takes its rise in Berry Pond, in Hancock, Berkshire county, Massachusetts, the peculiar location of which renders it worthy of a passing notice. The pond, which is about three miles above the dam and covers an area of some 20 acres, is situated on the summit of a mountain, only a very small extent of ground being higher than the level of the water. The pond is at an elevation of about one thousand feet above the surface of the reservoir formed by the dam.

CHAPTER XLIII.

DAM FOR ROCK AND SAND BOTTOM.

The stream on which the dam illustrated in this chapter is situated is known as the Little St. Francois, the location of the dam being 1½ miles northwest of Fredericktown, Madison County, Missouri. The course of the stream at this point is between high bluffs of porphyry, which seem to have been upheaved by some tremendous power beneath. The rocks are full of fissures, and the bed of the stream presents the appearance of large boulders, ten to fifteen feet in length and breadth, having been taken out at irregular intervals, and the cavities filled up with gravel and sand. The dam here referred to was built in 1869 by Mr. John T. Lee. He states that between the sloping solid rock bluff (shown in our engraving) and a large "hump" in the bed-rock in mid-stream, was a space filled with sand and gravel of unknown depth, in which he buried large white-oak logs, below the general level of the bed-rock, with the large ends down-stream, and extending about 8 feet below the face of the dam, on which to place the apron for this portion, no other part requiring any. Gains were cut in the round logs, and by chipping the bed-rock a place was made for the mud-sill as low down as possible. This mud-sill, running across the stream, was keyed in the gains in the logs and bolted to the bed-rock. The method adopted for bolting to the rock was to drill a hole from 6 to 10 inches deep, take an inch bolt and batter the end until it could just be pushed to the bottom of the hole, set it perpendicular and pour in melted lead or brimstone until the hole was full. The timber was then put down and fastened with a nut.

The dam is 110 feet long, 10 feet high from level of tail water, and 18 feet wide, and is built of sawn white-oak timber. The down-stream mud-sill is 10 by 12 inches; the cap-sill 8 by 10 inches; the upright posts 8 by 8 inches, and put 6 feet apart, mortised into the cap and mud-sills with short tenons and not pinned. There are also two up-stream mud-sills, the first put as low as possible, in a level position; and at intervals of 6 feet, timbers 6 by 8 inches, 18 feet long, are placed on the up-stream and down-stream mud-sills, serving as cross-ties, and bolted to the down-stream mud-sill with ¾ inch bolt and nut. The top up-stream mud-sill was next put down, and bolted down through the cross-tie to the lower sill, a nut being used wherever access could be had to it on the under side with a wrench. The face or down-stream side of the dam inclines up-stream about one foot from the perpendicular, and the cap-sill is bolted to the solid bluff. The rafters, which are 3 by 8 inches and 2 feet apart, were put on in the following manner: a gain was cut in the upper corner of the top up-stream mud-sill, in which to place the foot of the rafter in such a manner that in order to slip down-stream it must slide up an inclined plane. The cap sill was also gained so that the rafter might have a bearing the full width of the sill. The rafter



DAM FOR ROCK AND SAND BOTTOM.

was gained at this end so as to give it a shoulder about ½ inch deep on the down-stream side of the cap-sill, and extended about 10 inches beyond the cap-sill, so that the water might fall clear of the mud-sill. Spikes 12 inches long were made out of ½ inch rod iron and driven with a sledge-hammer through the ends of the rafters (which were bored for the purpose) into the cap and lower sills. Under each rafter were put two braces, 4 by 6 inches, half the upper end of each brace being cut out to form a shoulder for the rafter, to which it was bolted with a ⅝ inch bolt and cut. The lower end of each brace stands on the solid bed-rock, the brace leaning up-stream.

The first plank was then put on the lower ends of the rafters, its edge being beveled so as to make a true face with the top mud-sill. The spiling was then put in at the up-stream foot of the dam, in the following manner: oak planks 10 inches wide and 1 inch thick were sharpened at one end, wedge-shape, from one side only, driven down and drawn up again, and the battered places re-sharpened until the whole edge was of uniform shape. The plank or spile was then set and nailed to both sills and the covering plank, the beveled side of the spile being down-stream, or next the dam. The row of spiling was then doubled, the second row being of the same lumber, breaking joints with the first row, but having its beveled side up instead of down stream. A filling of sand and gravel was put in, up to the top of the spiling on its upper side; and under the dam, against the two up-stream mud-sills, loose boulders were put in, extending up to and among the rafters for about one-third their length. The dam was then double-planked with inch boards, the first layer being of oak, the upper one of pine. The preference was given to pine as being less liable to warp in the sun. At the top of the dam, to finish it, a 2-inch oak plank was laid and well spiked on.

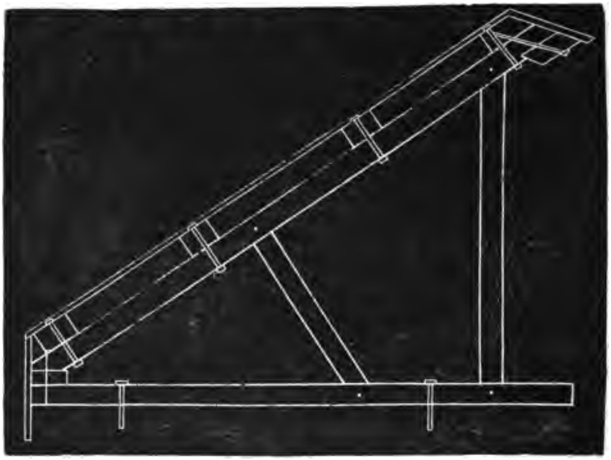
This dam has sustained several very heavy freshets, but at our last advices presented no appearance of yielding in any part, except the top plank just mentioned, which was badly torn by logs and trees, these coming in innumerable quantities during the freshets, and rushing through the narrows with great rapidity.

The dam contains, in the aggregate, 12,000 feet of lumber, costing, at $15 per thousand, $180. The labor of two workmen, who built the dam in thirty days, is put down at $60, and the cost of nails, bolts, etc., is estimated at $25. The total cost of the dam, therefore, by the builder's figures, was $265.

OVERHUNG APRON DAM.

On pages 108 and 109 we have illustrated two dams of the "overhung apron" construction; and we now give a sectional view of another of the same general nature, but differing in some of the practical details sufficiently to warrant a brief description. The builder of this dam is Mr. S. K. Cross, of Burlington, Kansas, the location being on the Neosho river, at that place. It was found necessary to remove a dam already in, which was of too light construction to be reliable,

and erect this in its stead. The river bed at this point is limestone. The bottom sills of the dam are 12 feet long, 10 by 12 inches, and are fastened to the rock by two iron bolts 3 feet long and 1¼ inches in diameter, the holes being drilled so small that a heavy sledge is



OVERHUNG APRON DAM.

required to drive the iron pin into the rock. The ¾-inch bolt shown at the foot of the dam up-stream, passing through the rafter, cross-timber and bottom sill, is put through the bottom sill before the sill is laid, the head of the bolt being underneath and the nut on top. The cross-timber, of which the end is here shown, resting on the bottom sill and supporting the foot of the rafters, is 10 inches thick, and need be hewed only on three sides. The same is the case with the lower cross-timber resting on the rafter. The two farther up the slope need only be hewed on two sides. All three are 10 inches thick with 10-inch face and are bolted to the rafters as shown, with ¾-inch bolts. At the upper end of the rafters the cross-timber on their upper side is differently hewed, as indicated in the cut, to adapt it to the planking of the "shoot" or "over-hang." The timber bolted at this point on the under side of the rafter is 6 by 12 inches, and dressed as shown, its purpose being to give the projection or apron the necessary strength. The rafters themselves are 16 feet long, 10 by 12 inches, and the posts and braces supporting them 10 inches square.

The whole upper surface of the dam, including the projection, is covered with 3-inch plank, all the planks being dressed on the edge with a bevel of ¼ inch. Before dressing and using, they are allowed to lie until about half seasoned, this being in all such cases an excel-

lent precaution against the injurious effects of either swelling or shrinking, one of which is likely to occur if very dry or entirely green lumber is used. The cut indicates sheet piling at the up-stream foot of the dam, against the ends of the bottom sills and rafters and the side of the cross-timber between them, and making a close joint with the foot of the planking. On a rock bottom, of course, this piling could not well be put in, and Mr. Cross, we believe, merely planks this part, covering it tightly and making the joints very close.

The bents of this dam are placed 8 feet apart, between centers. The total length of the dam is 290 feet, and its height 10 feet above the bottom sills. The Neosho rises to the height of 24 feet in extreme high water. Mr. Cross states that he gains 5 feet in head-race and tail-race, and places the cost of his dam at $7 per foot, lumber being worth $30 per 1,000 feet. The overhanging apron delivers the water so far below the dam that it cannot wash up under the sills to affect the foundation; and the builder is confident that the dam will last till it rots out.

CHAPTER XLIV.

RACE AND RESERVOIR EMBANKMENTS.

There is a radical difference in the conditions to be taken into account in constructing a dam for the purpose of raising the water in a river to a certain head and discharging the surplus, as compared with those which enter into the calculations for an embankment against standing water, or along the course of a deep and slowly moving body of water, as in a canal or race. In the case of a dam, there is but a comparatively narrow channel to be obstructed, and often a swift current is to be resisted; but on the other hand there are special means of fortifying the structure by securing it to the banks or to abutments, bolting its foundation to the river bed if it be of rock, building it with a curve or angle up stream so as to give it the elements of strength pertaining to an arch, and in various other ways providing against the special dangers to which it is exposed. The peculiar sources of damage affecting the stability of a dam are the force of the current and the tendency of the water to wash it in passing over, (unless delivered through a chute or waste-way) or to react upon and undermine it when discharged by an overfall. In an embankment for a race or reservoir, on the other hand, while the advantages of banks or abutments to serve as an anchorage are not afforded, and the principle of the arch cannot be introduced, the sources of danger are at the same time fewer in number, and the problem is perhaps as much simplified as the means for its solution are reduced. The largest scale on which works of this character are undertaken is reached in the construction of

levees and dykes; and in these but little difficulty would be encountered in securing the most ample strength and durability, were it not for the immense extent to which such works are necessarily carried, from which it results that the strictest economy in material and labor must be practised. A method of construction which would be thought but moderately expensive in a dam one hundred feet long would be absolutely ruinous in its cost if applied to a dyke or levee hundreds of miles in extent; and even when carried no farther than the embankment of a reservoir it would often require an impracticable outlay, as in this instance the burden falls on a single individual and is not borne by the whole community as in the case of a public work of this nature.

It follows that in the construction of embankments selection must be made from but few different kinds of material, and these of a cheap description—clay, sand and loam being the chief elements available for the purpose—and that the question of the plan of building resolves itself mainly into two points, the breadth of base and the angle of the slope. Of the three materials above mentioned, we have in previous chapters given the preference strongly to sand and loam, in connection with gravel and rock, recommending the use of clay only to a very limited extent, and mixed with the other substances named. Our chief ground for taking this view is the tendency of clay to maintain its position when passages are worked through it, leaving these breaches open to be worn wider and wider, finally destroying the cohesion of the whole mass. Sand or loam, on the contrary, especially the former, will pour in and close a gap which may be accidentally made, and a leak may thus be stopped, in many cases, without any actual repair being required. This point, we observe, is recognized even by authorities which on general grounds advocate the use of clay. A commissioner of levees in one of the western States alludes to clay banks as being peculiarly liable to the attacks of craw-fish, which dig holes through them from the water side, and seize upon the small fish or water insects which pass in with the flow. He remarks that the clay embankments give the craw-fish every facility for his work; but that he cannot operate in sand, as the hole falls in as soon as made. He therefore advises that a wall of sand be carried up in a clay embankment, and urges this matter as one of great importance.

There is a marked distinction between the use of clay as a filling in crib-work, where a current is constantly seeking to force its way through, and the employment of the same material for a race or reservoir embankment, where its weight and solidity give it superior value. Except for the requirement of sand as a protection against craw-fish, it may be doubted whether a levee or embankment should not, in all cases where practicable, be built chiefly of clay. It is by far the heaviest of the three materials here under consideration, the weight of stiff clay being 135 lbs. per cubic foot, while that of loam is 124 lbs., and of light sand only 95 lbs. per cubic foot. No other single point in the construction of an embankment is of greater importance than that

of weight, as this, with the proper breadth of base in proportion to height, is the sole dependence for the solidity of the work. As to its impenetrability, which is another important item, it must be borne in mind that there is not the same liability to leakage in an embankment against comparatively still water as in a crib or filling against which a current is constantly directed, and over which the water frequently flows—to say nothing of the eddies, whirlpools, reacting currents and underwash which are perpetually threatening the safety of a dam. A clay embankment, therefore, which has its slopes not too steeply pitched, its material firmly packed down, and its face on the water side suitably protected, is as reliable a work as can be desired for the purpose it is to meet. It must be admitted that the use of sand for the whole body of the embankment, though it is frequently practised on account of the greater convenience of obtaining it, is open to serious objections. It is neither cohesive nor impervious; even the winds, as well as the waves and currents, have power to carry it before them, and if the water once succeeds in penetrating it in such a way that the leak does not instantly close from above, it will wear a channel with great rapidity, speedily enlarging to a crevasse. Loam is much less objectionable in this respect, as it is not only nearly thirty per cent. heavier, but is also much more cohesive and firm.

The slope which should be presented by the sides of an embankment is of course greatly dependent on the kind of material of which it is composed. The "standing angle" or "angle of repose" of the three substances above mentioned—that is, the steepness of slope they will bear without sliding, when subjected to no other disturbing cause than that of their own gravity, is found to be, for sand, an angle of 30 degrees with the horizon; for firm loam, 36 to 45 degrees; and for clay, 55 degrees. In other words, supposing a pile to be made of each of these materials, coming to a point at the top, and having a perpendicular face on one side, as, for instance, if a bank of this kind be thrown up against a vertical wall, it is necessary that a bank of sand, in order not to slide or slip of its own weight, should have 1 foot, 9 inches base for every foot of height; for loam, about 1 foot, 3 inches base is necessary to 1 foot of height; while for clay, 8 to 12 inches base to each foot of height is sufficient. This being independent of all other forces or pressures than the weight of the material itself, the slope must be much more gradual, or in other words the base must be much wider in proportion to the height, in an embankment against water, than is indicated by these figures; and the farther this excess of width in the base is carried beyond what the theoretical "angle of repose" would require, the safer will be the embankment. In practice, these mathematical proportions are in fact almost entirely disregarded, and the more sure although perhaps less scientific rule is adopted of giving the base so great a width as to provide against any possible tendency to slip; but the fact remains that for sand a much more gradual slope is necessary than for either loam or clay, and for clay a steeper slope may be permitted than for either of the others. In the

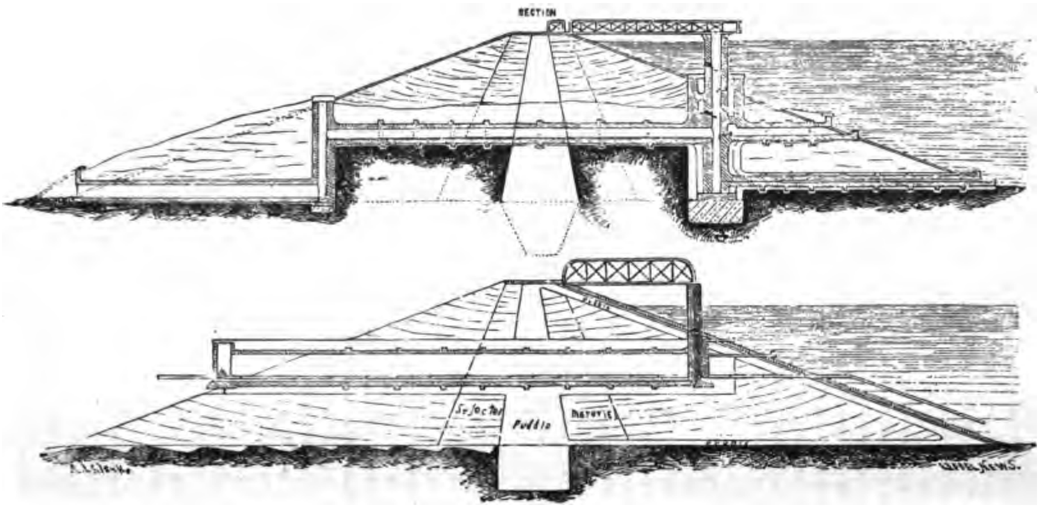
embankments of the Welland in England a base of 70 feet is given for a height of 8 feet, and on the Ouse, with 8 feet height and a breadth of 10 feet on the crown, the base is 60 feet wide. In other localities the base is 5 or 6 feet to 1 foot of height, divided, as to the slopes, by giving on the water side 3 or 4 feet base, and on the land side 2 feet base to every foot of vertical elevation. On the sea coast a still more gradual slope is given, being in many cases 4 or 5 feet to 1 foot to seaward, and 2 or 3 to 1 to landward. All these, it will be seen, are safe and substantial embankments, constructed rather with a view to permanent durability than to an immediate saving of expense; and this is a rule which can be confidently recommended in all works of this class, whether for public or private benefit.

The height to which embankments should be carried is subject to variation according to circumstances; but the rule ordinarily adopted is to make the crown from 3 to 5 feet above high-water mark. The breadth of crown is still more variable, ranging in different localities from 3 feet to 12 feet or more, the latter being an exceptional figure.

CHAPTER XLV.

RACE AND RESERVOIR EMBANKMENTS—(*Continued*).

The necessity of adapting the slope of an embankment, especially on the water side, to the disturbing causes which will operate upon it, and the fact that it is better to err on the side of safety than otherwise, making the slope more gradual than is absolutely required rather than too steep, need not be further urged, having been fully demonstrated in the preceding chapter. The almost invariable tendency of earth to lose its stability in some measure when subjected to the action of water, and the fact that its impermeability cannot be depended upon with certainty, render it necessary that the nature as well as the breadth of the foundation should be carefully attended to. There are, it is true, many cases in which embankments which were made by simply heaping up earth, without any special precautions to make it water tight, have stood an indefinite length of time without exhibiting any defect; but in these cases the desired result has been secured by a lavish use of material without regard to economy, as in some localities in India, where the cheapness of labor rendered it unnecessary to make such close calculations on this item as are elsewhere required. For a safe and permanent foundation, resort is sometimes had to a puddle wall with a "muck ditch" for its underlying support; the usefulness of this ditch being, however, strongly disputed, on the assumption that the natural surface of the ground is itself a more reliable foundation in many cases, the ditch being necessary only where the natural surface is loose and sandy, and by digging a ditch through it to a



RESERVOIR EMBANKMENTS.

reasonable depth a firmer subsoil can be reached. Again, many embankments have been successfully constructed uoon a foundation of brush, especially where the soil of the locality is light and unstable. This method is employed in building macadamized roads in marshy districts in England, and in dykes and embankments in Holland. Ireland and Canada. The most effectual manner of utilizing the brush is to put it down in two, three or four layers, their total thickness, when compressed by the weight of the overlying materials, to be from 4 to 6 feet; the brush to consist of branches of trees, as straight and tough as can be conveniently obtained, not too heavy, and of sufficient length to reach at each end within ten or twelve feet of the extremity of the slope of the embankment—the brush, however, not lying directly across the foundation, but placed aslant, each successive layer crossing the preceding after the manner of lattice work. The lowest layer may be pinned to the gronnd, and each of the succeeding layers to the one beneath it, by means of wooden forks; and when this method is adopted, the result is considered equally satisfactory with that obtained by the use of fascines, which are small bundles of brush tied up like a birch broom. In fact, the foundation can be more firmly knit and wrought together if simple brush is used than if fascines were employed.

There are also certain excellent methods of utilizing sand in works of this class, notwithstanding its weakness as a material for a simple embankment. A sand bank with small brush and clay intermixed, and the slopes faced with a firm material, has been found extremely durable. The use of sand piles, which is a somewhat novel substitute for piles of wood or iron, has been very successfully practised by English and French engineers. The method of setting such piles is very simple, and in a soft and deep soil, upon which a heavy embankment is to be placed, they are believed to afford the utmost attainable degree of security. Wooden piles are first driven, in rows along the middle and toward the sides of the foundation, and then withdrawn, the holes thus made being instantly filled with sand, which must be rammed down as firmly as possible as it is put in. Where the work is extensive enongh to justify it, machinery may be employed by which a number of piles may be driven, withdrawn and the holes filled simultaneously; and an iron cylinder. with internal screw-threads for sinking and raising, is sometimes used to facilitate the work. But a light lift-ram or a heavy sledge will often answer the purpose sufficiently, and the piles may be driven one by one, each being separately finished before beginning on the next. The depth to which they should be sunk will depend, of course, upon the nature of the soil, but need seldom exceed 6 or 7 feet. They should be 12 or 18 inches in diameter, and may be put from 6 to 10 feet apart. If the embankment is very heavy, it is well to have two or even three rows of piles in the central portion of the base, under what is to be the crown, and another row toward the outer edge of each slope; and the piles should be so arranged that the rows will "break joints," so to speak, the piles in one row not being directly opposite or in line with those in the next, but alternating like the spots on a chequer-board. It is somewhat sur-

prising, in view of the unstable character of sand as a material to be used in bulk, unsupported by other elements, that it should be found so productive of strength when employed in this manner; but it is nevertheless a fact that its power of resistance in the form of piles, both in their lateral and transverse section, is superior to that obtained by almost any other form of construction, except those of the most expensive character. In an experiment by a corps of Engish engineers, nine piles, 4 feet, 3 inches long and 8 inches in diameter, were driven into a very soft soil, their distance apart being 16 inches between centers. To drive them, a weight of 200 lbs. was let fall from a height of 3½ feet, the driving being continued until the piles yielded only about ¼ inch at each stroke, after which they were settled about one-fifth of an inch farther by placing upon them a load of ten tons. They were then withdrawn, the holes filled with sand, and 16 more piles sunk in the same way, the whole occupying a total area of 36 square feet. Under a weight of about 1,000 lbs. there was only a settlement of one-twenty-fifth of an inch, and under 30 tons weight, after a month had elapsed, the total amount of settling was only three-fifths of an inch. On the whole, it may be safely stated that a foundation of sand piles, especially if covered with layers of brush in the manner already described, will constitute, even in loose, light or marshy soil, a solid support for a heavy embankment, the slope being made sufficiently gradual to prevent any liability to slip, and the face protected against wash. It may also be remarked that where the soil is so firm that piling of any sort is not required, additional strength is often given to the foundation by spreading on the natural surface a thick and level coating of sand, to which is added, if the ground is very wet, one part of hydraulic lime to six parts of sand. This is too expensive a method for works which are to be carried to a great extent, but may be adopted with good results in the embanking of a race or reservoir of limited area.

The introduction of a puddle wall is so often resorted to in the construction of embankments that it deserves a few explanatory remarks, and we also give in connection with this chapter two illustrations of the manner of applying this principle in embanking operations. A rude substitute for puddling is found in many embankments in which the earth has been rendered very firm and compact by the tread of the workmen employed in depositing it; but this is chiefly the case in Eastern countries, where the work is often done entirely by hand, and the bank is therefore well tramped as it is carried up, without any express outlay for the purpose. It is also true that in any low embankment of very gradual slope, and composed of firm, tenacious clay, the puddle wall is unnecessary; but in the majority of cases it has been found most expedient, on the score of ultimate economy of material and stability of the work, to carry up an interior wall of the kind referred to, and also to arrange the other materials in relation to it so as to give the most secure protection to the base and interior of the embankment. In the two figures of our engraving, examples are given

of the methods adopted by the best European engineers, the second figure showing some advantageous features not embraced in the first. It will be seen that the puddle wall is in both cases carried down below the natural surface of the ground, there being in this instance a bed of rock or solid sub-soil which is thus reached, and the base of the puddle wall being worked together and blended with it as thoroughly as possible, a nearly impenetrable barrier is thus presented to the water. Where there is no such solid underlying stratum, as has been already remarked, there is nothing to be gained by sinking the wall below the natural level of the ground; but in such cases it is well to loosen the surface of the ground to a depth of 6 inches or a foot, in order to unite with it the base of the puddle and in fact of the whole embankment as closely as possible; and the sod which may thus require to be taken off may afterward serve a highly useful purpose as a coating for the water side of the embankment. It is also worthy of note, that all grass, roots or other decomposable matter must be removed from the surface on which the foundation is to be made, whether it is subsequently used to sod the exterior slope or not.

In both the embankments we have illustrated, however, the ditch system at the base of the puddle wall is adopted. In the first figure this ditch has sloping sides, being much narrower at the bottom than at top; in the second it has perpendicular sides. In both, the puddle wall tapers from the ditch up to the crown of the embankment, being thickest where it has to withstand the greatest pressure. The pressure of water against a barrier thus erected against it is directly as its depth; and the shape of the barrier must of course conform more or less accurately to this law of pressure. The earthworks which we here illustrate are of the kind required where large bodies of water are to be enclosed, the lower figure representing, in fact, a cross-section of the embankment of the Biddeford (England) Water Works. For such cases, a breadth of 10 feet of puddle wall at the level of the surface of the water is considered necessary for absolute safety; but in works of the kind where a less powerful pressure is to be sustained, the wall may be considerably reduced from that figure. The manner in which the remaining portions of the embankments are built is plainly indicated in the cuts. In the lower one especially, the arrangement of the materials used is a prominent feature, their relative position being such as to give the maximum degree of security. To this end, selected material comprising the soundest and most tenacious and impermeable of the substances to compose the embankment, is placed next to the puddle wall, on each side of it; although, as it is from the water side that the chief danger of a breach is to be apprehended, it would seem a still wiser method to place the best materials all on that side. Why the arrangement here shown is so generally adopted it would be difficult to state; but such appears, to be the case. In the Biddeford embankment, it will be observed the water slope is protected by a layer or coating of puddle extending from the foot of the slope to the crown of the embankment; and outside of this is a layer of peat.

Another method, which is strongly recommended by many, is to cover the whole of the water slope with a layer of stone compactly laid by hand. Again, such embankments are often protected by growing grass thickly upon the top and sides—an excellent method, for which Bermuda grass is said to be peculiarly adapted, as it grows very rapidly, and thrives both in sunshine and shade. A coating of loam should first be spread on to give the necessary fertility. This mode of strengthening an embankment is practised on many lines of railroad, and is equally adaptable to the protection of earthworks against water, one of its advantages being that the annual decay of the grass tops affords each year a new though of course very light coating of compact matter on the slope, which in time adds greatly to its strength. In foreign countries thick ropes of twisted straw are often used for the covering of embankments, being pinned to the bank with forked sticks, the ropes lying so close together as to form a mat, which is still further strengthened by the grass or other vegetation working through and interlacing with it. In other cases, fascines, brushwood, and sometimes large slabs of stone are laid upon the slopes of embankments to shield them from injury. A choice can readily be made from the different methods and materials we have enumerated, each builder suiting his work to the facilities at his command and the conditions he has to deal with. It should be mentioned that where the slope is protected by a layer of puddle, as shown in the second figure of our engraving, it is found beneficial to mix small stones or furnace cinders with the puddle to prevent the attacks of vermin. Fresh-water crabs have been known in some cases to take all the "pointing" from a wall of masonry, the mortar being highly useful to them as a material for the growth of their shells.

In both our illustrations is shown a system of pipes, culvert, valve-tower, etc., for providing the necessary outlet to the reservoir. The practice of conducting the discharge-pipe through or under the body of the embankment is strongly condemned by the best engineers, as it is thus rendered inaccessible in case a defect occurs and repairs are rendered necessary; and even if protected by a culvert, there is in such cases great danger of fracture resulting from the unequal settling of the embankment. Either with or without a culvert, therefore, there is incurred by this plan constant liability to accident, which may lead to serious damage to the embankment, and will certainly cause great inconvenience and less in various ways. In the methods we have illustrated, the brick or stone culvert is located at a point one-half or two-thirds of the way up the embankment, and is made large enough to enable a man to enter it. A still safer plan is to carry the culvert around the end of the embankment, or to run a tunnel through the ground beneath and entirely clear of the embankment, there being in either of these cases no liability of injury to the culvert by the irregular settling of the earthwork. The plan shown in our first figure is substantially that designed by Mr. Rawlinson, an eminent civil engineer. The bottom of the culvert is in this case some 25 feet above the foot of

the water slope of the embankment, the syphon pipe passing through the culvert. A shaft inside the embankment and connected with the horizontal culvert, contains the valves which conduct the water-supply from the reservoir. It will be seen that the valves, inlet pipes, etc., are so arranged and operated that the engineer has at all times full control of them, and all the parts are readily accessible for repair. In the cross-section of the Biddeford embankment, also, similar arrangements for the discharge of water are shown, with the same communication of the culvert with the valve-tower, and the location in the latter of the inlet pipes at different heights, admitting of the drawing of water from the reservoir from points near the surface, where it is most likely to be pure. A float is sometimes attached to the end of a pipe inside the reservoir, this pipe moving up and down between guides as the water rises and falls, and having at its other end a flexible joint connecting it with the outlet pipe.

PART II.

A VALUABLE HYDRAULIC TABLE.—LOSS OF HEAD BY FRICTION OF WATER IN PIPES

The following Table, the calculations for which have been carefully made from the formula of Weisbach, the celebrated German scientist, will be found extremely useful in determining the available power of water moving at any velocity from one to twenty feet per second, through pipes from three to thirty inches inside diameter. The length of pipe for which the table is calculated is 100 feet. But as the loss of head by friction varies in the same direct ratio as the length of the pipe, the amount of such loss in a pipe of greater or less length than 100 feet can be readily ascertained.

For example: to find the loss of head in a pipe 47 feet long, 7 inches inside diameter, discharging 192 cubic feet of water per minute. This rate of discharge, as will be seen by the table, indicates a velocity of 12 feet per second. The loss of head is found in the column for 7-inch pipe, opposite the figure 12 in the column of velocities, viz: 7.41 feet for a pipe 100 feet long. For a pipe 47 feet long it will be 47-100 of 7.41 feet, or 7.41 multiplied by .47, making 3.48 feet, decimals below the second place being dropped.

For a pipe 125 feet long, 10 inches inside diameter, discharging 490 cubic feet of water per minute: Velocity shown in table, 15 feet per second; loss of head for 100 ft. pipe, 7.9 feet; therefore

$$\begin{array}{r} 1.25 \\ 7.9 \\ \hline 1125 \\ 875 \\ \hline 9.875 \end{array}$$

9.875 feet of head lost in 125 feet, the given length of pipe.

LOSS OF HEAD BY FRICTION OF WATER IN PIPES.

CALCULATED FOR PIPES 100 FEET LONG.

Velocity of Water through Pipe in Feet per Second.	INSIDE DIAMETER OF PIPE IN INCHES.											
	3		4		5		6		7		8	
	Discharge per Min. in Cubic Feet……..	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet…….	No of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet ……	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet……	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet…….	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet…….	No. of Ft. Loss of head due to friction
1	2.95	.196	5.22	.147	8.17	.118	11.77	.098	16.03	.084	20.88	.074
2	5.89	.659	10.44	.494	16.34	.395	23.54	.329	32.05	.282	41.76	.247
3	8.83	1.35	15.67	1.02	24.51	.815	35.32	.679	48.08	.581	62 64	.509
4	11.80	2.28	20.89	1.71	32.69	1.37	47.09	1.14	64.11	.977	83.52	.856
5	14.70	3.43	26 12	2.57	40.87	2.05	58.87	1.71	80.15	1.47	104.40	1.28
6	17.70	4.78	31.34	3.59	49.05	2 87	70.64	2.39	96.18	2.05	125.28	1.79
7	20.60	6.35	36.57	4.77	57.22	3.81	82.41	3.18	112.21	2.73	146.16	2.39
8	23.56	8.14	41.79	6.11	65.40	4.89	94.19	4.07	128.24	3.49	167.04	3.06
9	26.51	10.12	47.02	7.59	73.57	6.07	105.97	5.06	144.27	4 34	187.92	3.79
10	29.45	12.32	52.24	9.24	81.75	7 39	117.74	6.16	160.30	5.28	208.80	4.62
11	32.40	14.71	57.47	11.03	89.92	8.82	129 52	7.36	176.34	6.31	229.68	5.52
12	35.34	17.31	62.70	12.98	98.10	10.38	141.30	8.65	192 37	7.41	250.56	6.49
13	38.33	20.10	67.92	15.08	106.27	12 06	153.07	10.05	208.40	8.61	271.44	7.54
14	41.23	23.12	73.15	17.34	114.45	13.87	164.85	11.56	224.43	9.91	292.32	8.67
15	44.20	26.32	78.38	19.74	122.62	15.79	176 63	13.16	240.46	11.28	313.20	9.87
16	47.12	29.72	83.60	22 29	130.80	17.83	188.40	14.86	256.48	12.74	334.08	11.15
17	50.05	33.33	88.83	25.00	138.97	20.00	200.18	16.67	272.51	14.29	354 96	12.50
18	53.00	37 14	94.05	27.86	147.15	22 29	211.96	18.57	288.54	15.92	375.84	13.93
19	55 95	41.12	99.28	30.84	155.32	24.67	223.73	20 56	304.57	17.62	396.72	15.42
20	58.89	45.32	104.50	33.99	163.50	27 19	235.51	22.66	320 60	19.42	417.60	17.00

LOSS OF HEAD BY FRICTION OF WATER IN PIPES.—CONTINUED.

Calculated for Pipes 100 Feet Long.

Velocity of Water through Pipe in Feet per Second.	INSIDE DIAMETER OF PIPE IN INCHES.											
	9		10		11		12		13		14	
	Discharge per Min. in Cubic Feet.......	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet.......	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet.......	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet.......	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet.......	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet.......	No. of Ft. Loss of head due to friction
1	26.47	.065	32 70	.059	39.55	.054	47.10	.049	55.30	.045	64.08	.042
2	52.94	.220	65.40	.198	79.10	.180	94.20	.164	110.60	.152	128.16	.141
3	79.41	.450	98.15	.407	118 65	.370	141.30	.339	165.90	.313	192.24	.291
4	105.90	.760	130.85	.685	158.20	.623	188.40	.570	221.20	.527	256.32	.489
5	132.37	1.14	163.50	1.03	197.76	.932	235.40	.855	276.50	.789	320.40	.735
6	158.84	1.59	196.20	1.43	237.30	1.30	282.50	1.20	331.80	1.10	384.48	1.03
7	185.31	2.12	228 90	1.90	276.85	1.73	329.60	1.59	387.10	1.46	448.57	1.36
8	211.80	2.71	261.60	2.45	316.40	2.23	376.70	2.04	442.40	1.88	512.66	1.75
9	238.29	3.37	294.29	3.03	355.95	2.76	423.80	2.53	497.70	2.33	576.75	2.17
10	264.77	4.11	327.00	3.70	395.50	3.36	470.90	3.08	553.00	2.85	640.84	2.64
11	291.26	4.90	359.70	4.41	435.05	4.01	518.00	3.68	608.30	3.39	704.93	3.15
12	317.74	5.77	392.39	5.19	474.62	4.72	565.10	4.32	663.60	3.99	769.02	3.71
13	344.22	6.70	425.09	6.03	514.17	5.48	612.20	5.03	718 90	4.64	833.10	4.30
14	370.70	7.71	457.79	6.93	553.72	6.30	659.30	5.78	774.20	5.33	897.18	4.95
15	397.18	8.77	490.49	7.90	593.27	7.18	706.35	6.58	829.50	6.08	961.27	5.64
16	423.65	9.91	523.18	8.92	632.82	8.11	753 45	7.43	884.75	6.86	1025.36	6.37
17	450.13	11.11	555.88	10.00	672.37	9.09	800.50	8.33	940.00	7.69	1089.45	7.15
18	476.61	12.38	588.58	11.14	711.92	10.13	847.60	9.29	995.30	8.57	1153.54	7.96
19	503.08	13.71	621.28	12.34	751.52	11.22	894.70	10.28	1050.60	9.49	1217.63	8.81
20	529.56	15.11	653.98	13.60	791.07	12.36	941.75	11.33	1105.90	10.46	1281.72	9.71

LOSS OF HEAD BY FRICTION OF WATER IN PIPES.—Continued.

Calculated for Pipes 100 Feet Long.

Velocity of Water through Pipe in Feet per Second.	INSIDE DIAMETER OF PIPE IN INCHES.											
	15		16		17		18		19		20	
	Discharge per Min. in Cubic Feet........	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet........	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet........	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet........	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet........	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet........	No. of Ft. Loss of head due to friction
1	73.58	.039	83.68	.037	94.56	.035	106 00	.033	118.09	.031	130.87	.029
2	147.16	.132	167.36	.123	189.12	.116	212.00	.110	236.18	.104	261.74	.099
3	220.74	.272	251.04	.255	283.68	.239	318.00	.225	354.27	.214	392.61	.204
4	294.32	.457	334.72	.428	378.24	.403	424.00	.380	472.36	.361	523 48	.343
5	367.90	.683	418.40	.640	472.80	.601	530.00	.570	590.45	.537	654.35	.515
6	441.48	.957	502.08	.895	567.36	.841	636.00	.795	708.54	753	785.22	.715
7	515.07	1.27	585.76	1.19	661.92	1.12	742.00	1.06	826.63	1.00	916.09	.950
8	588.66	1.63	669.45	1.53	756.48	1.44	848.00	1.36	944.72	1.29	1046.96	1.23
9	662.25	2.02	753.14	1.89	851.04	1.78	954.00	1.68	1062.81	1.59	1177.83	1.51
10	735.84	2.46	836 83	2.31	945 60	2.18	1060.00	2.06	1180.90	1.95	1308.70	1.85
11	809.43	2.94	920.52	2.76	1040.16	2.59	1166.00	2.45	1298.99	2.32	1439.57	2.21
12	883.02	3.46	1004.21	3.24	1134.72	3.05	1272.00	2.89	1417.08	2.73	1570.44	2.59
13	956.60	4.02	1087.90	3.77	1229 28	3.55	1378.00	3.35	1535.17	3.17	1701.31	3.02
14	1030.18	4.62	1171.59	4.33	1323.84	4.08	1484.00	3.86	1653.26	3.65	1832.18	3.47
15	1103.77	5.26	1255.28	4.93	1418.40	4 65	1590.00	4.38	1771.35	4.16	1963.05	3.95
16	1177.36	5.94	1338.96	5.58	1512.96	5.25	1696.00	4.96	1889.44	4.69	2093.92	4.46
17	1250.95	6.67	1422.64	6.25	1607.52	5.88	1802.00	5.55	2007.53	5 26	2224.79	5.00
18	1324.54	7.43	1506.32	6.97	1702.08	6.55	1908.00	6.19	2125.62	5.86	2355.66	5.57
19	1398.13	8.22	1590.00	7.71	1796.64	7.26	2014.00	6.86	2243 71	6.49	2486.53	6.17
20	1471.72	9.06	1673.68	8.50	1891.20	8.00	2120.00	7.56	2361.80	7.16	2617.40	6.80

LOSS OF HEAD BY FRICTION OF WATER IN PIPES.—Continued.

Calculated for Pipes 100 Feet Long.

Velocity of Water through Pipe in Feet per Second.	INSIDE DIAMETER OF PIPE IN INCHES.									
	22		24		26		28		30	
	Discharge per Min. in Cubic Feet........	No of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet........	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet........	No. of Ft. Loss of head due to friction	Discharge per Min. in Cubic Feet........	No. of Ft. Loss of head due to friction
1	158.36	.027	188.44	.025	221.13	.023	256.56	.021	294.44	.019
2	316.72	.090	376.88	.082	442.26	.076	513.12	.071	588.88	.066
3	475.08	.185	565.32	.169	663.39	.157	769.68	.145	883.32	.136
4	633.44	.312	753.76	.285	884.52	.263	1026.24	.245	1177.76	.228
5	791.80	.466	942.20	.428	1105.65	.394	1282.80	.368	1472.20	.342
6	950.16	.650	1130.64	.600	1326.78	.550	1539.36	.515	1766.64	.478
7	1108.52	.865	1319.08	.795	1547.91	.730	1795.92	.680	2061.08	.635
8	1266.88	1.12	1507.52	1.02	1769.04	.940	2052.48	.875	2355.52	.815
9	1425.24	1.38	1695.96	1.27	1990.17	1.17	2309.04	1.08	2649.96	1.01
10	1583.60	1.68	1884.40	1.54	2211.30	1.42	2565.60	1.32	2944.40	1.23
11	1741.96	2.01	2072.84	1.84	2432.43	1.69	2822.16	1.57	3238.84	1.47
12	1900.32	2.36	2261.28	2.16	2653.56	2.00	3078.72	1.86	3533.28	1.73
13	2058.68	2.74	2449.72	2.52	2874.69	2.32	3335.28	2.15	3827.72	2.01
14	2217.04	3.15	2638.16	2.89	3095.82	2.67	3591.84	2.48	4122.16	2.31
15	2375.40	3.59	2826.60	3.29	3316.95	3.04	3848.40	2.82	4416.60	2.63
16	2533.76	4.06	3015.04	3.72	3538.08	3.43	4104.96	3.19	4711.04	2.97
17	2692.12	4.55	3203.48	4.17	3759.21	3.85	4361.52	3.58	5005.48	3.33
18	2850.48	5.07	3391.92	4.65	3980.34	4.29	4618.08	3.98	5299.92	3.72
19	3008.84	5.61	3580.36	5.14	4201.47	4.75	4874.64	4.41	5594.36	4.11
20	3167.20	6.18	3768.80	5.67	4422.60	5.23	5131.20	4.86	5888.80	4.53

USEFUL FACTS IN HYDRAULICS.

Doubling the diameter of a pipe increases the capacity four times.

The ordinary speed to run a pump is 100 feet of piston per minute.

To find the area of a piston, square the diameter and multiply by .7854.

Each nominal horse power of boilers requires 1 cubic foot of water per hour.

A gallon of water (U. S. standard) weighs $8\frac{1}{3}$ lbs., and contains 231 cubic inches.

A cubic foot of water weighs $62\frac{1}{2}$ lbs., and contains 1,728 cubic inches, or $7\frac{1}{2}$ gallons.

Circular apertures are most effective for discharging water, since they have less frictional surface for the same area.

Hydraulics treats of fluids in motion, and especially of water, the machinery and works for raising and conducting it, its action in canals, races and rivers, its adaptation to water wheels as prime movers, etc.

To find the velocity in feet per minute necessary to discharge a given volume of water in a given time, multiply the number of cubic feet of water by 144, and divide the product by the area of the pipe in inches.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434. (Approximately every foot of elevation is considered equal to $\frac{1}{2}$ lb. pressure per square inch).

To find the diameter of a pump cylinder to move a given quantity of water per minute (100 feet of piston being the speed), divide the number of gallons by 4, then extract the square root, and the result will be the diameter in inches.

Vertical apertures or slits on the side and running near to the bottom of vessels, issue the water with a mean velocity due at the sill or lower edge of opening, or with the velocity due to a point four-ninths of the whole height of head.

The time occupied in discharging equal quantities of water under equal heads, through pipes of equal lengths, will be different for varying forms, and proportionally as follows: for a *straight line*, 90; for a *true curve*, 100; and for a *right angle*, 140.

To find the horse power necessary to elevate water to a given height, multiply the total weight of column of water in lbs. by the velocity per minute in feet, and divide the product by 33,000 (an allowance of 25 per cent. should be added for friction, etc.)

To find the area of a required pipe, the volume and velocity of water being given, multiply the number of cubic feet of water by 144, and divide the product by the velocity in feet per minute. The area being found, it is easy to get the diameter of pipe necessary.

To find the capacity of a cylinder in gallons. Multiplying the area in inches by the length of stroke in inches will give the total number of cubic inches: divide this amount by 231 (which is the cubical contents of a gallon in inches), and the product is the capacity in gallons.

The area of the steam piston, multiplied by the steam pressure, gives the total amount of pressure exerted. The area of the water piston, multiplied by the pressure of water per square inch, gives the resistance. A margin must be made between the power and the resistance to move the pistons at the required speed.

With thin plates on the bottom or sides of reservoir, the stream, issuing through circular openings, converges toward a point at about one-half its diameter from the outside of orifice, reducing the quantity discharged nearly five-eighths from the quantity that the velocity corresponding to the head should discharge.

With a horizontal cylindrical tube, the length and diameter being the same, the discharge will be the same as through a plain aperture. A horizontal cylindrical tube having greater length than diameter, increases the discharge, and the discharge will continue to increase until the length reaches four times the diameter.

To find the quantity of water elevated in one minute running at 100 feet of piston per minute: Square the diameter of water cylinder in inches and multiply by 4. Example: The capacity of a 5-inch cylinder is desired. The square of the diameter (5 inches) is 25, which, multiplied by 4, gives 100, which is the number of gallons per minute (approximately).

The best form of aperture for giving the greatest flow of water, is a conical aperture, whose greater base is the aperture, the height or length of the action of cone being half the diameter of aperture, and the area of the small opening to the area of the large opening as 10 to 16; there will be no contraction of the vein, and consequently the greatest attainable discharge will be the result.

Water in falling is actuated by the same law as other falling bodies; passing through 1 foot in $\frac{1}{4}$ of a second, 4 feet in $\frac{1}{2}$ second, 9 feet in $\frac{3}{4}$ of a second, and so on; hence its velocity flowing through an aperture in the side of a reservoir, bulkhead or any vessel, is the same as that of a heavy body falling freely from a height equal to the distance between the middle of the aperture or hole to the surface of water below.

PROTECTION OF DAMS FROM MUSKRATS.

An experienced mill owner says: "I have lately seen it stated that the yearly damage by muskrats on the Erie Canal is not less $50,000. In the Southern States there are several kinds of borers, and it is said that most of the breaks in the levees of the Mississippi river are caused by their depredations. The muskrat always begins his burrow under water, going in horizontally—sometimes nearly through an embankment—then working up above the water level, and there making numerous passages and apartments which are occupied sometimes by a community of thirty or more. If, in boring into a bank, they meet a wall that they cannot penetrate, they seldom dig far downwards to get beneath it, and never, I think, more than ten or fifteen inches

below the water at the bottom of the pond. They prefer to dig in soft earth, but if such is not to be found, they will penetrate the hardest gravel, and even cut their way through plank. Now all that is needed for a perfect protection against them is a thin wall, begun about 2 feet below the water, and carried up with the embankment as high as the water is expected ever to rise. The wall may be made of brick or flat stones set edgewise with cement mortar; or preferably, of concrete, made of cement and gravel; need not be but 2 inches thick, or cost more than 3 or 4 cents per superficial foot. It will strike most persons at first thought that a 2-inch wall would be too frail to be of any use, but I know from an experience of six years that it is not only a perfect protection against vermin, but will also prevent the passage of water from pressure. If made of good materials, it becomes in a few months nearly as hard and strong as stone, and will resist considerable pressure. An embankment so protected was overflowed and partly washed away by the breaking of a dam above, and when the flood subsided, a part of the wall was left standing 4 feet higher than the gravel on either side of it. Puddling is frequently resorted to, to prevent the percolation of water through gravel, but is not as effectual for that purpose as concrete wall, and no protection whatever against muskrats. For the wall, I use 1 part Rosendale cement to 5 of gravel. One barrel of cement will make 150 to 200 feet of wall; and three men will make from 200 to 300 feet in a day. The gravel should be a mixture of fine and coarse, with no stones larger than two inches diameter, With Portland cement, 14 parts of gravel make good work, which makes it somewhat cheaper than Rosendale. After various experiments, I think that I have hit upon the best mode of forming the wall, viz.: In a mould, made of 2 sheets of iron, each 4 to 5 feet long, one 15 inches wide, the other 18 inches. Each is bent its whole length 12 inches from the opposite edge, at an angle of say 25 degrees, so that when placed side by side, 2 inches apart, the top edges will flare sufficiently to make it convenient to fill the mould with a shovel. A block 2 inches square and 12 inches long fills the space at the forward end of the mould, and should have a hole bored obliquely through it to receive a brace 3 feet long, so that when the opposite end rests on the ground the block will be kept in a perpendicular position. Now fill the mould 1 foot high with concrete, ramming it down with a beater made of a ½-inch hardwood board, and at the same time fill with earth te the same height on the outsides; then draw each sheet in end nearly its length, and proceed as before. Each sheet should have a handle at the fore end, near the upper corner, made of 5-16 wire, with a hook attached to one of them, to connect with the other, to keep them snug to the block."

Another mill owner's plan: Dig a channel sufficiently deep to be beyond all possibility of the muskrats going below it, and fill it with chips from the tin shop, in connection with gravel.

Another: Coat the dam with gravel, letting the gravel table out in the water, and leaving it about 12 inches thick along the water's edge.

To which an Illinois miller adds: The best method to protect a dam against the attacks of muskrats is to gravel the same to the water side. Sand and pebble stones, banks of which are found in the bed of almost every stream, is the best. Repeat this until the water ceases to wash it down, when it will stay permanently. This will also save the trouble of cutting loose the ice in spring. Sand is getting warm quicker than clay, and the dam is in such shape that ice will peel off without harm. Embankments which are made of alternate layers of clay and stone, or of clay and stone mixed, are also safe. Any break in a dam repaired while water is running through is unsafe, and will break again, even without the aid of muskrats. To keep the water out, cut willows, tie the same in bundles of sufficient length, and spike them down in front of the break, one on top of the other. If the break is very large, put them in V shape, and with the aid of manure, tan bark or sand, you soon will have it dry. If the bottom is soft, throw in stones, ram down with a wooden rammer, and keep on filling with stones and ground, ramming well where it joins the sides, and this part is secure against water and muskrats.

VELOCITY OF FLOWING WATER.

The mean or average velocity of a flowing stream is found by scientific experiments to be from .81 to .83 of the maximum velocity, or that in the line of the current. At half depth of the stream the velocity is .915, and at the bottom .83, of that at the surface. The average depth of flowing water is found by setting off the breadth of the stream into any convenient number of divisions, ascertaining the depth of each, and adding these depths together; their sum being then divided by the number of divisions of the stream, the quotient will be the average depth. The area of the stream is obtained by multiplying the mean depth by the breadth. To obtain the volume of flowing water, multiply the area of the stream by the velocity of the flow in feet; the product will be the volume in cubic feet. The velocity of water in a canal should be proportioned to the character of the bed. To prevent the deposit of slime and growth of grass, a velocity of about 8 inches per second is requisite, and the mean velocity, over a slimy bed, should not exceed this limit. Over common clay it should not be more than 6 inches per second; over sand or small gravel, 1 foot; and on shingle or stony bottom it may range from 3 to 6 feet per second.

A MINER'S INCH.

A miner's inch of water is a quantity that will flow through an inch aperture with a free discharge and under a constant pressure of 6 inches above the top of the opening. An aperture $12\frac{1}{2}$ by $15\frac{3}{4}$ inches under pressure of 6 inches above the top of the opening will discharge 100

inches, and is the basis of all measurements where water is retailed in small quantities in the States of California and Nevada. A miner's inch will discharge a quantity of water equal to 2,250 cubic feet or about 17,000 gallons, weighing 139,500 lbs., in 24 hours. Water will hold in suspension or solution .167 of its entire volume, i. e., an inch of water (miner's inch) having a grade of 4 inches to the rod, will carry off in 24 hours, a distance of 10 miles, 10 tons of quartz, sand and iron. At one gravel mine in Nevada county, California, 24 cubic yards, or 40 tons of detritus or tailings, as the washed material is called, are moved from 3 to 15 miles every 24 hours.

THICKNESS AND WEIGHT OF PIPE UNDER VARIOUS HEADS OF WATER.

The following table, by the Warren Foundry and Machine Co., shows the thickness of metal and weight per length of different sizes of pipe under various heads of water—a "length" of 2-inch pipe being 9 feet, and of all the other sizes 12 feet. The pipe is cast vertically in dry sand:

Size.	50 Ft. Head.		100 Ft. Head.		150 Ft. Head.		200 Ft. Head.		250 Ft. Head.	
	Thickness of Metal.	Weight per Length.	Thickness of Metal.	Weight per Length.	Thickness of Metal.	Weight per Length.	Thickness of Metal.	Weight per Length.	Thickness of Metal.	Weight per Length.
2	.2946	63	.3126	67½	.3306	72	.3486	76½	.3666	81
3	.3449	144	.3539	149	.3629	153	.3719	157	.3809	161
4	.3612	197	.3732	204	.3852	211	.3972	218	.4092	226
6	.3938	315	.4118	330	.4298	345	.4478	361	.4658	377
8	.4224	445	.4504	475	.4744	502	.4984	529	.5224	557
10	.4590	600	.4890	641	.5190	682	.5490	723	.5790	766
12	.4916	768	.5276	826	.5636	885	.5996	944	.6356	1004
14	.5242	952	.5662	1041	.6082	1111	.6502	1191	.6922	1272
16	.5801	1215	.6048	1253	.6528	1360	.7008	1463	.7488	1568
18	.5894	1370	.6434	1500	.6974	1630	.7514	1761	.8054	1894
20	.6220	1603	.6820	1763	.7420	1924	.8020	2086	.8620	2248
24	.6870	2120	.7592	2349	.8312	2580	.9032	2811	.9752	3045
30	.7850	3020	.8750	3376	.9650	3735	1.0550	4095	1.1450	4458
36	.8828	4070	.9908	4581	1.0988	5096	1.2068	5613	1.3148	6133
48	1.0784	6616	1.2224	7521	1.3664	8431	1.5104	9340	1.6544	10269

CONTENTS OF CISTERNS AND TANKS.

The following table gives the number of barrels (31½ gallons) in cisterns or tanks from 5 ft. to 30 ft. in diameter, and from 5 ft. to 20 ft. in depth. For tanks of tapering form, the diameter should be measured

at a distance from the large end equal to 4-10ths of the total depth; for example, if the depth of a tapering tank is 15 feet, the diameter is found by measuring at a point 6 feet from the large end:

Diameter in Feet.

Depth in Feet.	5	6	7	8	9	10	11	12	13	14	15	16	17
5	23.3	33.6	45.7	59.7	75.5	93.2	112.8	134.3	157.6	182.8	209.8	238.7	269.5
6	28.0	40.3	54.8	71.7	90.6	111.9	135.4	161.1	189.1	219.3	251.8	286.5	323.4
7	32.7	47.0	64.0	83.6	105.7	130.6	158.0	188.0	220.6	255.9	293.7	334.2	377.3
8	37.3	53.7	73.1	95.5	120.9	149.2	180.5	214.8	252.1	292.4	335.7	382.0	431.2
9	42.0	60.4	82.2	107.4	136.0	167.9	203.1	241.7	283.7	329.0	377.7	429.7	485.1
10	46.7	67.1	91.4	119.4	151.1	186.5	225.7	268.6	315.2	365.5	419.6	477.4	539.0
11	51.3	73.9	100.5	131.3	166.2	205.1	248.2	295.4	346.7	402.1	461.6	525.2	592.9
12	56.0	80.6	109.7	143.2	181.3	223.8	270.8	322.3	378.2	438.6	503.5	572.9	646.8
13	60.7	87.3	118.8	155.2	196.4	242.4	293.4	349.1	409.7	475.2	545.5	620.7	700.7
14	65.3	94.0	127.9	167.1	211.5	261.1	315.9	376.0	441.3	511.8	587.5	668.2	754.6
15	70.0	100.7	137.1	179.0	226.6	289.8	338.5	402.8	472.8	548.3	629.4	716.2	808.5
16	74.7	107.4	146.2	191.0	241.7	298.4	361.1	429.7	504.3	584.9	671.4	673.9	862.4
17	79.3	114.1	155.4	202.9	256.8	317.0	383.6	456.6	535.8	621.4	713.4	811.6	916.3
18	84.0	120.9	164.5	214.8	272.0	335.7	406.2	483.4	567.3	658.0	755.3	859.4	970.2
19	88.7	127.6	173.6	226.8	287.0	354.3	428.8	510.5	598.0	694.5	797.3	907.1	1024.1
20	93.3	134.3	182.8	238.7	302.1	373.0	451.3	537.1	630.4	731.1	839.3	954.9	1078.0

Diameter in Feet.

Depth in Feet.	18	19	20	21	22	23	24	25	26	27	28	29	30
5	302.1	336.6	373.0	411.2	451.3	493.3	537.1	582.8	630.4	679.8	731.1	784.2	839.3
6	362.6	404.0	447.6	493.5	541.6	592.0	644.5	699.4	756.5	815.8	877.3	941.1	1007.1
7	423.0	471.3	522.2	575.7	631.9	690.6	752.0	815.9	882.5	951.7	1023.5	1097.9	1175.0
8	483.4	538.6	596.8	658.0	722.1	789.3	859.4	932.5	1008.6	1087.7	1169.7	1254.8	1342.8
9	543.8	605.9	671.4	740.2	812.4	887.9	966.8	1049.1	1134.7	1223.6	1316.0	1411.6	1510.7
10	604.3	673.3	746.0	822.5	902.7	986.6	1074.2	1165.6	1260.8	1359.6	1462.2	1568.5	1678.5
11	667.7	740.6	820.6	904.7	992.9	1085.2	1181.7	1282.2	1386.8	1495.6	1608.7	1725.3	1846.4
12	725.1	807.9	895.2	987.0	1083.2	1183.9	1289.1	1398.7	1512.9	1631.5	1754.6	1882.2	2014.2
13	785.5	875.2	969.8	1069.2	1173.5	1282.6	1396.5	1515.3	1639.0	1767 5	1900.8	2039.0	2182.0
14	846.0	942.6	1044.4	1151.5	1263.7	1381.2	1503.9	1631.9	1765.1	1903.4	2047 1	2195.9	2343.9
15	906.4	1009.9	1119.0	1233.7	1354.0	1479.9	1611.4	1748.4	1891.1	2039.4	2193.3	2352.7	2517.8
16	966.8	1077.2	1193.6	1315.9	1444.3	1578.5	1718.8	1865.0	2017.2	2175.4	2339.5	2509.6	2685.6
17	1027.2	1044.6	1268.2	1398.2	1534.5	1677.2	1826 2	1981.6	2143.3	2311.3	2485.7	2666.4	2853.5
18	1087.7	1211.9	1342.8	1480.4	1624.8	1775.9	1933.6	2098.1	2269.4	2447.3	2631.9	2823.3	3021.3
19	1148.1	1279.2	1417.4	1562.7	1715.1	1874.5	2041.1	2214.7	2395.4	2583.2	2778.1	2980.1	3189.2
20	1208.5	1346.5	1492.0	1644.9	1805.3	1973.2	2148.5	2321.2	2521.5	2719.2	2924.4	3137.0	3357.0

TABLE FOR SMALL CISTERNS.

The capacity of cisterns (in gallons) from 2 ft. to 5 ft. in diameter, and from 3 ft. to 10 ft. in depth, is given in the following table:

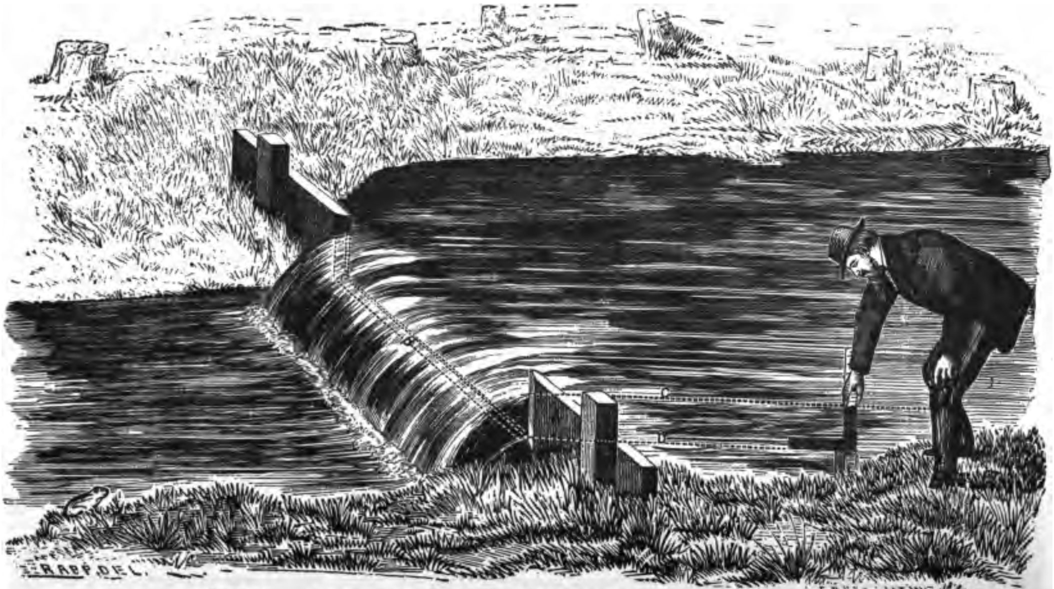
Diameter in Feet.

Depth in Feet.	2	2½	3	3½	4	4½	5
3	70.5	110.16	158.62	215.89	281.99	356.91	440.64
4	93.9	146.88	211.49	287.85	375.98	475.88	587.52
5	117.5	183.60	264.36	359.81	469.98	594.85	734.40
6	140.9	220.32	317.23	431.77	563.98	713.82	881.28
7	164.5	257.04	370.10	503.73	657.97	832.79	1028.16
8	187.9	293.76	422 97	575.69	751.96	951.76	1175.04
9	211.5	330.48	475.84	647.65	845.95	1070.73	1321.90
10	234.9	367.20	528.71	719.61	939.94	1189.70	1468.80

WEIR DAM FOR MEASUREMENT OF WATER.

In the engraving and table accompanying this article are shown the method of ascertaining, approximately, the quantity of water flowing in a stream—an important matter in estimating the amount of power which can be derived from it. The plate represents a weir dam across a small stream. Where it is convenient to use a single board, as is shown in the cut, select one that is long enough to reach across the stream, resting in the bank at each end. Cut a notch in the board sufficient in depth to pass all the water to be measured, and not more than two-thirds of the width of the stream in length. The bottom of notch B in the board A should be beveled on the down-stream side; the ends of the notch should also be beveled on the same side, and within one-eighth of an inch of the upper side of the board, leaving the edge almost sharp. E is a stake driven in the bottom of stream several feet above the board or dam, and should be driven down to the level of notch B, this level being easily found as the water is beginning to spill over the board. After the water has come to a stand and reached its greatest depth, a careful measurement can be made of the depth of water over the top of stake E, as illustrated in the cut by the man with square and measure in his hand. Such measurement gives the true depth of water passing over the notch, since, if measured directly on the notch or the board, the curvature of the water in passing would reduce the depth, giving the improper measure. Although, where accuracy is not required, such a method will give a fair estimate of the quantity of water, in all cases it is best to make the measurement over the stake. The line D is a level from the bottom of notch B to the top of stake E; while the dotted line C represents the top of the water, and the distance between the *lines* or from the top of stake, gives the *true depth* or spill over the weir. The lines have, in the cut, the appearance of running over the top of the board; but this is owing to the fact that they pass behind it, and, for the purpose of illustration, the reader is supposed to look through the board and the post. The surface of the water below the board should not be nearer the notch B than *ten* inches, that the flow of water over the notch may not be impeded. Neither should the nature of the channel above the board be such as to force or hurry the water to the board, but it should be of ample width and depth to allow the water to approach the notch and board steadily and quietly. If the water passes the channel rapidly it will be forced over the notch, and a larger quantity will pass than if allowed to spill from a large body moving slowly.

When the depth of water over the stake E is known, the quantity of water passing can be easily calculated by reference to the Weir Table on page 166. This table gives the number of cubic feet of water passing per minute over a weir for each inch in breadth, from one-sixteenth of an inch in depth to twenty-five inches depth. The figures 1, 2, 3, etc., in the first and last perpendicular columns, are the inches depth of water over weir, while the first or top horizontal column represents



WEIR DAM FOR MEASUREMENT OF WATER.

WEIR TABLE FROM ONE-SIXTEENTH INCH DEPTH TO TWENTY-FIVE INCHES DEPTH.

Inches		1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16		Inches
		.000	.01	.03	.05	.07	.09	.11	.14	.17	.20	.23	.26	.30	.33	.36		
1	.40	.43	.47	.51	.55	.60	.65	.70	.74	.78	.83	.87	.93	.98	1.03	1.08	.40	1
2	1.14	1.19	1.24	1.30	1.36	1.41	1.47	1.52	1.59	1.65	1.71	1.77	1.83	1.89	1.96	2.02	1.14	2
3	2.09	2.16	2.23	2.29	2.36	2.43	2.50	2.57	2.63	2.71	2.78	2.85	2.92	2.99	3.07	3.14	2.09	3
4	3.22	3.29	3.37	3.44	3.52	3.60	3.68	3.75	3.83	3.91	3.99	4.07	4.16	4.24	4.32	4.41	3.22	4
5	4.50	4.58	4.67	4.75	4.84	4.92	5.01	5.10	5.18	5.27	5.36	5.45	5.54	5.63	5.72	5.81	4.50	5
6	5.90	6.00	6.09	6.18	6.28	6.37	6.47	6.56	6.65	6.75	6.85	6.95	7.05	7.15	7.25	7.35	5.90	6
7	7.44	7.54	7.64	7.74	7.84	7.94	8.05	8.15	8.25	8.35	8.45	8.55	8.66	8.76	8.86	8.97	7.44	7
8	9.10	9.20	9.31	9.42	9.52	9.63	9.74	9.85	9.96	10.07	10.18	10.29	10.40	10.51	10.62	10.73	9.10	8
9	10.86	10.97	11.08	11.19	11.31	11.42	11.54	11.65	11.77	11.88	12.00	12.12	12.23	12.35	12.47	12.59	10.86	9
10	12.71	12.83	13.95	13.07	13.19	13.31	13.43	13.55	13.67	13.80	13.93	14.04	14.16	14.30	14.42	14.55	12.71	10
11	14.67	14.79	14.92	15.05	15.18	15.30	15.43	15.56	15.67	15.81	15.96	16.08	16.20	16.34	16.46	16.59	14.67	11
12	16.73	16.86	16.99	17.12	17.26	17.39	17.52	17.65	17.78	17.91	18.05	18.18	18.32	18.45	18.58	18.72	16.73	12
13	18.87	19.01	19.14	19.28	19.42	19.55	19.69	19.83	19.97	20.10	20.24	20.38	20.52	20.66	20.80	20.94	18.87	13
14	21.09	21.23	21.37	21.48	21.65	21.79	21.94	22.08	22.22	22.35	22.51	22.65	22.79	22.94	23.08	23.23	21.09	14
15	23.38	23.53	23.67	23.82	23.97	24.11	24.26	24.41	24.56	24.71	24.86	25.01	25.16	25.31	25.46	25.61	23.38	15
16	25.76	25.91	26.06	26.21	26.36	26.51	26.66	26.81	26.97	27.12	27.27	27.43	27.58	27.73	27.89	28.04	25.76	16
17	28.20	28.35	28.51	28.66	28.82	28.98	29.14	29.29	29.45	29.60	29.76	29.92	30.08	30.23	30.39	30.55	28.20	17
18	30.70	30.86	31.02	31.18	31.34	31.50	31.66	31.81	31.98	32.15	32.31	32.47	32.63	32.80	32.96	33.12	30.70	18
19	33.29	33.45	33.61	33.78	33.94	34.11	34.27	34.44	34.60	34.77	34.94	35.10	35.27	35.44	35.60	35.77	33.29	19
20	35.94	36.10	36.27	34.46	36.60	37.87	36.94	37.11	37.28	37.45	37.62	37.79	37.96	38.14	38.31	38.48	35.94	20
21	38.65	38.82	39.00	39.17	39.34	39.52	39.69	39.86	40.04	40.21	40.39	40.56	40.73	40.91	41.09	41.26	38.65	21
22	41.43	41.60	41.78	41.96	42.13	42.31	42.49	42.67	42.84	43.02	43.20	43.38	43.56	43.74	43.92	44.10	41.43	22
23	44.28	44.46	44.64	44.82	45.00	45.18	45.38	45.53	45.71	45.90	46.08	46.26	46.43	46.63	46.81	47.00	44.28	23
24	47.18	47.36	47.55	47.72	47.91	48.09	48.28	48.46	48.65	48.83	49.02	49.20	49.39	49.58	49.76	49.93	47.18	24

NOTE.—The extreme right and left hand perpendicular columns of heavy figures, in the above table, represent whole inches depth of water over a weir board; while the top horizontal line of fractions, shows parts of an inch depth over weir. The second horizontal line indicates the quantity of water flowing over a weir board for each fractional part of an inch depth, under which the figures may be found; and the third horizontal line gives the quantity for one inch and a fraction of an inch depth, and so on. All these measurements are made for one inch width of spill.

fractional parts of an inch, from one-sixteenth to sixteen-sixteenths. The body of table shows the cubic feet and decimal parts of a cubic foot that will pass each minute for each depth of weir, from one-sixteenth to twenty-five inches, as before stated. But each result is for but one inch in width; so, for any particular number of inches breadth of weir the result obtained in table must be multiplied by the number of inches of breadth the weir may be. For example, suppose the notch or weir be 20 inches wide, and the water at stake E 5½ inches deep; in the first or last column find the figure 5, follow the horizontal column until the perpendicular column is reached containing ½ at the top. In the square where these two columns meet will be found 5.18 (five and eighteen hundredths) cubic feet. This is the quantity of water that will pass for each inch in width; but, since the supposed weir was 20 inches wide, this result must be multiplied by 20, which gives 103.60 (one hundred and three and six-tenths) cubic feet per minute. In this manner the water passing any width of weir, of any depth from one-sixteenth of an inch to twenty-five inches depth, can be easily calculated.

TABLE OF SPOUTING VELOCITY AND DISCHARGE OF WATER FOR GATE ORIFICES.

B	E	F	B	E	F	B	E	F	B	E	F
1	17.64	0.62	11	58.51	2.03	21	80.84	2.81	31	98.22	3.41
2	24.95	0.86	12	61.11	2.12	22	82.75	2.87	32	99.80	3.46
3	30.55	1.16	13	63.61	2.21	23	84.61	2.93	33	101.34	3.52
4	35.28	1.22	14	66.01	2.29	24	86.43	3.00	34	102.87	3.57
5	39.43	1.37	15	68.33	2.37	25	88.21	3.06	35	104.37	3.63
6	43.21	1.50	16	70.57	2.45	26	89.96	3.12	36	105.85	3.67
7	46.68	1.62	17	72.74	2.53	27	91.67	3.18	37	107.31	3.72
8	49.90	1.73	18	74.85	2.60	28	93.35	3.24	38	108.75	3.77
9	52.92	1.84	19	76.90	2 67	29	95.00	3.30	39	110.17	3.82
10	55.79	1.94	20	78.90	2.75	30	96.65	3.35	40	111.58	3.87

B. Head in inches. E. Spouting velocity in inches and decimals. F. Cubic feet discharged per minute for each square inch of orifice.

Of course this method is not so accurate as the weir measurement, but in many cases it answers the purpose quite as well.

The quantities of water discharged in equal times by the same apertures under different heads are nearly as the square roots of the corresponding heads, the heads being measured above the apertures.

The quantities of water discharged in the same time through different sized apertures, under different heads, are to one another in the compound ratio of the areas of the apertures, and of the square roots of the heights of heads above the centers of the apertures.

SPEED OF WOOD-WORKING MACHINERY.

[First & Pryibil.]

Velocity of Circular Saw at periphery, 10,000 to 11,000 *per minute*.
" Band Saw for Scroll work, 3,000 feet on stuff from 1 to 4 inch thick, and 3,500 feet on stuff from 2 to 10 inch thick.
" Gang Saws, 20 inch stroke, 185 to 200 strokes per minute.
" Scroll Saws, from 5 to 6 inch stroke, 400 and 500 strokes per minute.

Travel of Planing Machines, according to diameter of cutters, heads 4½ inch diameter 4,500 feet, and Cutter Heads 6 to 7 inch, 4,000 feet per minute.

Speed of Wood Carving Machine Cutters, 7,000 to 10,000 revolutions, according to large or small machines.
" Machine Augers, 1½ inch diameter, 800 per minute in soft wood; one-third less for hard wood, and smaller Diameter Augers in proportion.

Reslitting or Resawing Band Saws shall run at periphery of 5,500 feet per minute.

Log Cutting Band Saw shall run at a periphery of 5,500 feet per minute.

Oak requires about half more power than pine, and other woods in proportion.

Belt 1 inch wide, which travels 750 feet, is considered one horse-power.

TO JOIN THE ENDS OF BAND SAWS.

File the ends of the band on opposite sides, to form two wedged-shaped ends, having a lap of say ¾ inch long, which when laid with their beveled and filed sides together shall form a good joint of the same thickness as blade. Now clamp the ends on a piece of board, with the back of the blade toward you, with the lap brought fair together, and see that the back of the blade is straight. Cut a piece of "silver solder," large enough to cover the lap, lay it between the lapped portion with a little pulverized borax. Now, having a piece cut out of your board, say three inches wide, directly under your lap, heat your soldering tongs to a bright "cherry red," and hold them pinched firmly on the lap until the solder flows freely from under the joint, then cool off the tongs and soldered portion of saw by pouring water upon the same, without relieving the pressure, until nearly cold. Try a file on both sides of the blade, and should it be harder than the other part of the blade, re-heat your tongs a little, and draw the temper by pressing the tongs upon the hard portion of the blade till partially heated, but not upon the lap, as it will weaken your joint. File off the solder and joint to the same thickness as other parts, and the soldering of your band is completed.

ADVICE IN THE SELECTION AND USE OF FILES.

Always use a new file with a light pressure on the work till the needle-like points of the teeth are worn away. After this, a heavier pressure may be used with much less danger of breaking off the teeth at their base. Many new files are violently diminished half their efficiency by a few careless strokes when first applied to the work. Do not use a new file on the chilled or gritty skin of castings; or on a weld where borax or similar fluxes have been employed—no file can endure such usage.

Every filer should be required to keep a worn file with which first to attack the rough, gritty, or oxydized surface of iron work, and thereby pave the way for more efficient work with his sharp files. A piece of gritty or chilled casting that would rapidly destroy the cutting qualities of a new file would produce scarcely any damaging effect to a worn one.

In filing steel, better results can generally be obtained by using files of a grade not coarser than "2d Cut," finer grades being employed according to the finish and delicacy of the work under manipulation.

Persons using files should always seek to discover the fitness or adaptability of cut and form of files specially suited to their work. No one should expect the best results from a file on brass or spelter which was intended for use on iron and steel.

Consumers of files should see that they are furnished by the dealer or manufacturer with the full-weight article. This is always important, and especially in case re-cutting is desired. A full-weight file can be re-cut two or three times, while a light-weight will scarcely bear one re-cut, and give satisfaction.

The following table gives the proportionate lengths and diameters of standard round and square files:

Diameter (parts of inch).	1/8	3-16	1/4	3/8	1/2	5/8	3/4	7/8	1
Length in Inches...........	3 & 4	6	8	10	12	14	16	18	20

MANAGEMENT OF BELTS.

A leather belt, in order to run steadily and with the best effect, should have but one laced joint; and in making this joint the two ends should be cut at right angles with the sides. The holes will have less tendency to diminish the strength of the belt in the cross-section if they are cut with an oval punch. The laces should not be crossed on the inside, and care must be taken to put them in evenly and of equal strength at the two edges of the belt.

In case rivets are employed, the heads should be let in on the inside surface of the belt so as to leave no obstructing points to come in contact with the pulley, the washers being placed on the outer surface. Waxed ends used in connecting beveled and lapped ends should also be carefully confined within the surface on the inside of the belt, as they will work mischief by wearing if allowed to project.

The more nearly an equal thickness and perfect straightness are se-

cured in the belt throughout its whole length, the better it will perform its work. Dust, grease and lubricating oils should on no account be allowed to accumulate either on the belt or the pulley. If the motion is to be very rapid, the belt should if possible be endless,—that is, it should have none but permanent joints, and it is especially desirable that the density and dimensions should be uniform throughout, all unevenness of texture being carefully avoided.

SPLICING LEATHER BELTS.

The splicing of leather belts may be made, according to a contemporary, as strong as the solid leather by dissolving Nelson's opaque gelatine in acetic acid, using just enough of the acid to dissolve the gelatine on a warm place on an oven or boiler; the splices, which should be made quite thin, are then pasted with the cement, brought together and cramped between two pieces of wood. For a series of joints, the belt should be laid out on the floor, each splice separately pasted and rubbed on the top with a thin piece of wood, as much cement as possible being squeezed from between the joints. Leave over night until properly set.

TO MEASURE BELTING IN THE COIL.

Add the diameter of the hole, in inches, to to the outside diameter of the roll; multiply by the number of coils in the roll; then multiply this by the decimal .1309, and the product will be the number of feet in the roll. To have the exact length, the average diameter must be used if the roll is not perfectly round, and the fractional parts of an inch must not be omitted in the calculation.

BELTING RULES AND CALCULATIONS.—(*Hamilton.*)

Horse-power of a belt equals velocity in feet per minute, multiplied by the width—the sum divided by 1,000.

One inch single belt, moving at 1,000 feet per minute, equals 1 horse-power.

Double belts about 700 feet per minute, per 1 inch width, equals 1 horse-power.

For double belts of great length, over large pulleys, allow about 500 feet per minute per 1 inch of width per horse-power.

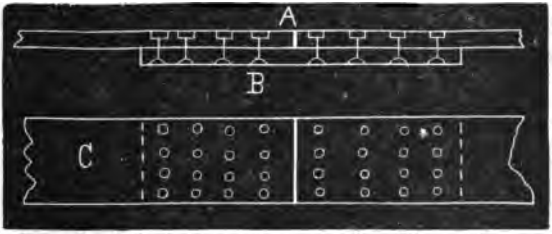
Power should be communicated through the lower running side of a belt; the upper side to carry the slack.

Average breaking weight of a belt, 3-16 multiplied by 1 inch wide —Leather, 530 lbs.: 3-ply rubber, 600 lbs.

The strength of a belt increases directly as its width. The co-efficient of safety for a laced belt is—for Leather, 1-16 breaking weight; for Rubber, ⅛ breaking weight.

FASTENING RUBBER BELTS.

In the accompanying sketch is shown a method of joining rubber belts which has been found by experience to be practical and reliable.



Draw the ends of the belt so as to meet at A. Then with copper rivets put on the piece B, of the same material, as shown in sketch. Small burrs or washers must be used on the rivet side, otherwise the rivets will tear out. C, shows the plain side of the belt and arrangement of rivets.

DISPOSITIONS OF THE QUARTER-TWIST BELT.

When two shafts are at or nearly at right angles with each other, and not in the same plane (Fig. 1), and it is desired to drive one from the other by two pulleys only and a connecting belt, experience has proved that certain conditions are necessary. In the first place, the distance between the near faces of the pulleys must not be less than four times the width of the belt. The pulleys A and B should be so placed that the belt will lead from the face of one to the centre of the face of the other, that is, so that *a plane passing through the centre of the face*

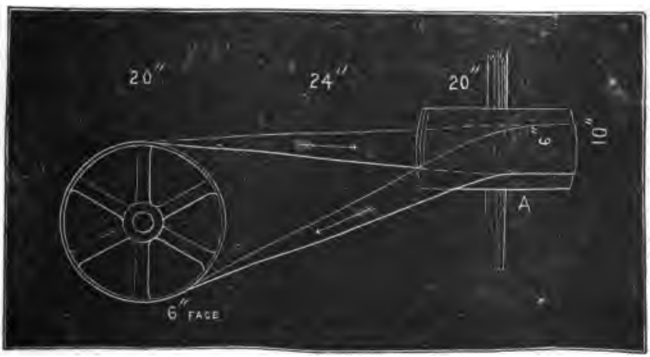


Fig. 1.

of one pulley will be tangent to that part of the face of the other from which the belt is running.

The above diagram gives the position and proper proportions referred to:

The pulley A, from which the belt deflects, should have a wider face than B, in the proportion of 10 to 6, and should be more rounding on the face than is usual, and the pulleys should be as small as may be to do the work, and should be of nearly equal size.

About 25 per cent. of belt contact is lost when the belt makes a quarter-turn, even when the pulleys are of the same size. We have noticed in the performance of a *leather* belt that the first 90° of lap on the pulley fit closely as in the ordinary straight belt arrangement; but in the second 90°, about half the width of the belt is forced from contact with the pulley by the strain in the substance of the belt, due chiefly to its imperfect elasticity, and primarily to the oblique deflection of the fold which is leaving the pulley.

With a belt perfectly elastic the same amount of contact, if not more, can be obtained, as with the open belt, since the belt would adhere to the face of the pulley up to the line of departure the same in one case as in the other.

Mr. L. H. Berry, of the Atlantic Works, Philadelphia, gives the particulars of a quarter-twist belt, arranged by him, and shown in Fig. 2, for driving a 54 inch circular saw, the periphery of which travels at the rate of 8,400 feet per minute, and the mandrel lying at right angles to the driving-shaft.

"On the mandrel is a 12-inch pulley, and on the driving-shaft, which runs horizontally 8 feet above, is a wooden drum 24 inches diameter, 8½ feet long, upon which the belt—a 10-inch heavy single leather, trav-

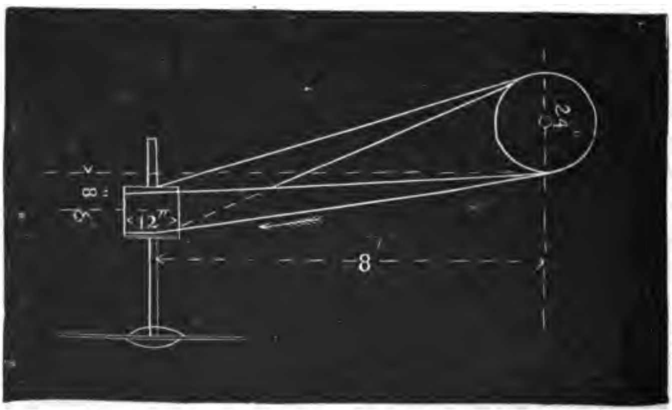


Fig. 2.

eling 1,800 feet per minute—traverses back and forth, following the reciprocating movement of the saw mandrel. The forward movement of the saw when cutting is at the rate of 60 feet per minute, and the return movement 120 feet per minute.

"From some cause (centrifugal force, perhaps, or because the belt was new, and, therefore, not as pliable as it would otherwise have been) the centre of the pulley had to be set 8 inches out of the path of the vertical line from the periphery of the drum. (See cut.)"

In Fig. 3, A is the driving pulley on a horizontal shaft; B the driven pulley on a mill-spindle or upright shaft; C the tightener or guide

Fig. 3.

pulley, which is placed at the proper angle for receiving the belt from B and delivering it to A. It has a short shaft running in bearings secured to a frame which slides vertically in fixed grooves, and may be raised to tighten the belt for driving, or lowered to slacken the belt for stopping, B, at pleasure. B. is made wide and straight on the face to admit of motion in raising and lowering the stones, as well as to allow of lead of belt by the different positions of C, which are due to length and tightness of belt.

A and C should be rounding on their faces. The cut shows the proper positions of the pulleys and shafts, and also gives good working proportions, the particulars having been obtained from machinery in use; but the motion of the belt, as shown, should be reversed.

The quarter-twist belt, with intermediate guide pulley, like Figs. 3 and 4, will permit of very short distance between the driving and driven

Fig. 4.

shafts. A case in practice may be cited, in which the driving pulley is 40 inches, the driven pulley 18 inches, and the guide pulley 16 inches in diameter; all of them are 8 inches face, and the shafts are 4 feet 7 inches from centre to centre, vertically.

This distance might be even less without injury to the belt. In the erection of this arrangement it was found necessary to set the face of the driven pulley one inch back of the centre of the face of the driving pulley, and to give the axis of the guide-pulley an inclination of 30° to the horizontal line.

When the shafts are at right angles, but not in the same plane, the belt running on four pulleys, as in Fig. 5: Let E be the *driving* shaft, with tight pulley, A, and loose pulley, B, and F the *driven* shaft, with tight pulley, D, and loose pulley, C; all the pulleys of same size and with rounded faces, in the usual way.

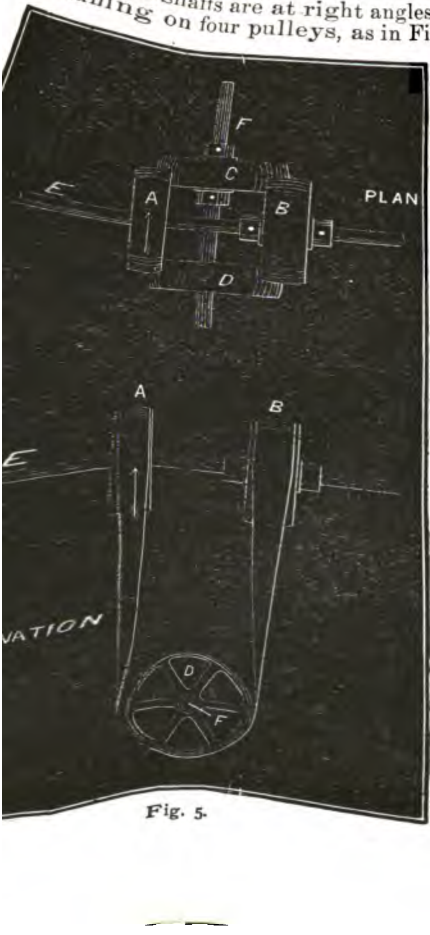


Fig. 5.

Let the pulleys be arranged in a square on the plan, whose side is the diameter of pulleys at centre of face, and let an endless belt be put on, as shown and run in the direction of the arrow. It will be noticed the loose pulleys, C and B, run in opposite directions from that of the shafts on which they turn; but since they carry the slack fold of the belt, they are relieved of heavy strain on the shafts. This is a good plan for wide belts when the shafts are a proper distance apart—say 10 times the breadth of the belt—and solve the sometimes difficult problem of carrying considerable power around a corner by a belt. There is no loss of contact of the belt on any of the pulleys of this system, and no lateral straining and tearing of the fibres of the belt, as in the usual quarter-twist arrangement, in which only two pulleys are used. The lower shaft may drive the upper one, as well, by changing the direction of the motion, or changing the relative positions of the tight and loose pulleys.

Figure 6 shows the usual method of transmitting power to shafts which are at or near right angles with the driver.

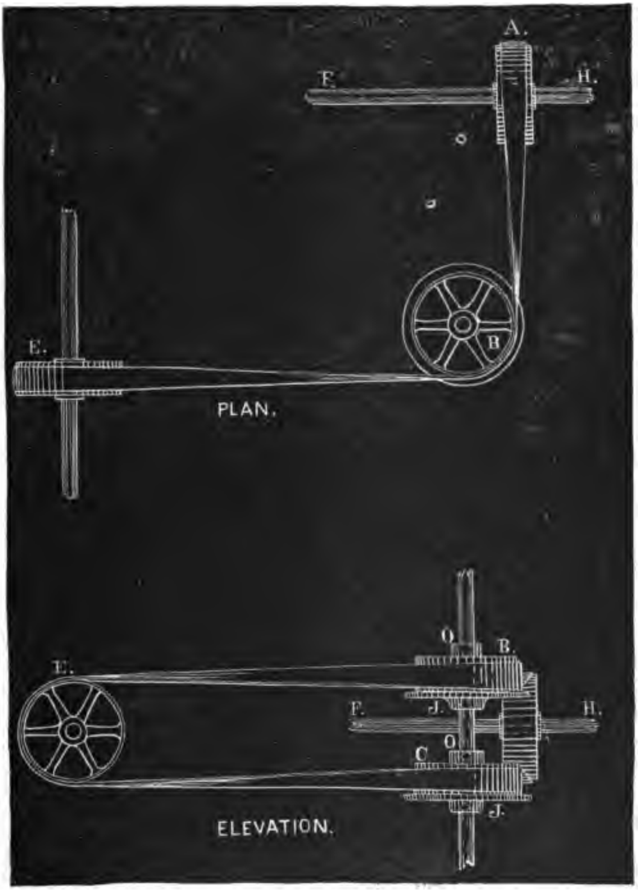


Fig. 6.

Let A be the driving pulley on the main shaft, F H; D and E driven pulleys on the counters, at right angle to the main. Place two upright shafts, each with a loose pulley, so that its face will be opposite the

middle of the face of A, one to the right and one to the left, over these pass a belt as shown in the cuts. The belt will run either way in both.

In Fig. 7 is illustrated a method of arranging a quarter-twist belt,

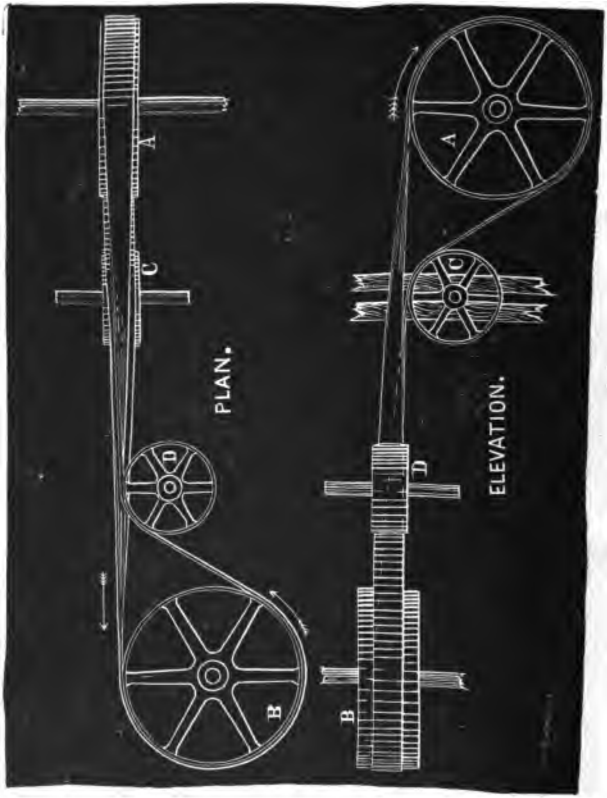


Fig. 7.

when the shafts are at right angles, but not in the same plane, the belt running on four pulleys. A is the driving pulley on a horizontal main line-shaft; B is the driven pulley on a mill-spindle or upright shaft; C is a tightener on a shaft parallel to the main shaft, with bearings, in a frame, which, with the pulley, can be raised or lowered when required to start or stop the pulley, B; D, is a guide pulley on a vertical shaft

running in fixed bearings. The course of the belt is indicated by the arrows. This plan may be resorted to when the pulley, A, cannot be placed on the main shaft directly from B.

[The foregoing article, with the seven illustrations accompanying it, is taken by permission from the valuable work entitled, "A Treatise on the Use of Belting for the Transmission of Power," by John H. Cooper, Mechanical Engineer. Published by Claxton, Remsen & Haffelfinger, Philadelphia.]

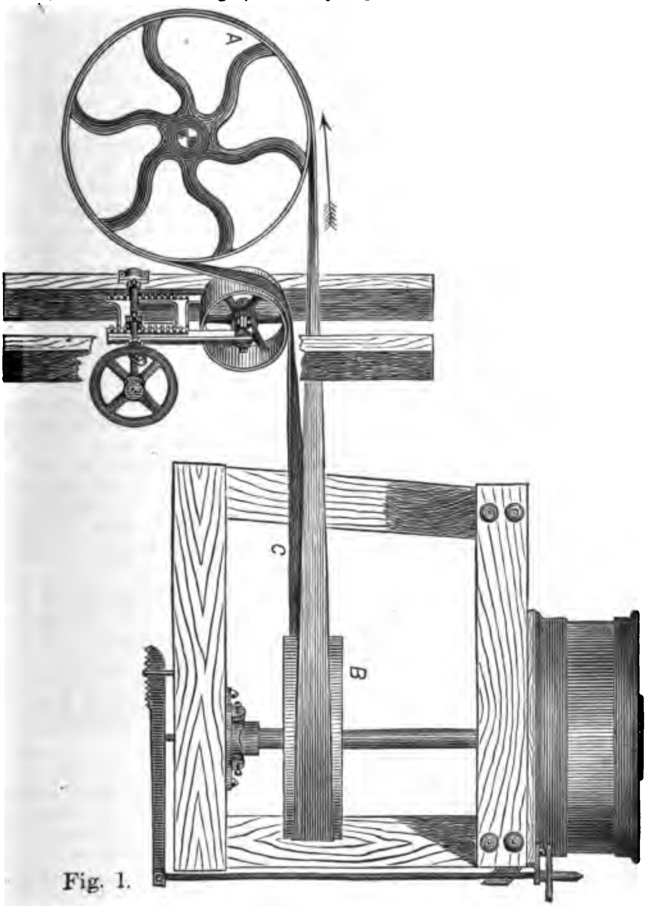


Fig. 1.

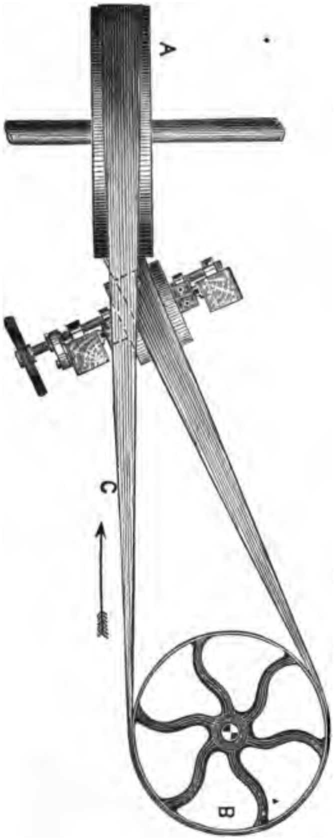


Fig. 2.

We also give in this connection two illustrations showing the method in which a mill-stone may be driven by a quarter-turn belt and tightener —aud the same arrangement may be applied to other kinds of machinery. In Fig. 1, which gives a side view or elevation, A indicates the driving pulley on the horizontal shaft, which is driven direct from the motive power; B the driven pulley on the mill-stone shaft; and C the slack side of the belt, which passes over the tightening pulley. The arrow indicates the direction in which the belt is run.

In Fig. 2, in which a plan or "down view" of this arrangement is given, the same letters indicate the same pulleys as in Fig. 1; but in Fig. 2, C is the tight side of the belt, which runs, as shown by the arrow, in the same direction as in Fig. 1. It will be seen that when used with the tightener or idle pulley, the quarter-turn belt requires a somewhat different arrangement or position of the pulleys doing the work from that necessary when the idler is not employed.

In Fig. 2 the mill-stone of course is not shown, but only the pulley B by which it is revolved.

TABLE OF HORSE POWER WHICH CAN BE SAFELY TRANSMITTED BY BELTING AT DIFFERENT VELOCITIES.

[By Samuel Webber, in Leffel News.]

FOR SINGLE BELTS.

Speed.	600 Feet per Min.	1,200 Feet per Min.	1,800 Feet per Min.	2,400 Feet per Min.	3,000 Feet per Min.	3,600 Feet per Min.	4.200 Feet per Min.	4,800 Feet per Min.	5,400 Feet per Min.	6,000 Feet per Min.
Width of Belt.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1 Inch.	1	2	3	4	5	6	7	8	9	10
2 "	2	4	6	8	10	12	14	16	18	20
3 "	3	6	9	12	15	18	21	24	27	30
4 "	4	8	12	16	20	24	28	32	36	40
6 "	6	12	18	24	30	36	42	48	54	60
8 "	8	16	24	32	40	48	56	64	72	80
10 "	10	20	30	40	50	60	70	80	90	100
12 "	12	24	36	48	60	72	84	96	108	120
16 "	16	32	48	64	80	96	112	128	144	160
20 "	20	40	60	80	100	120	140	160	180	200
24 "	24	48	72	96	120	144	168	192	216	240

FOR DOUBLE BELTS.

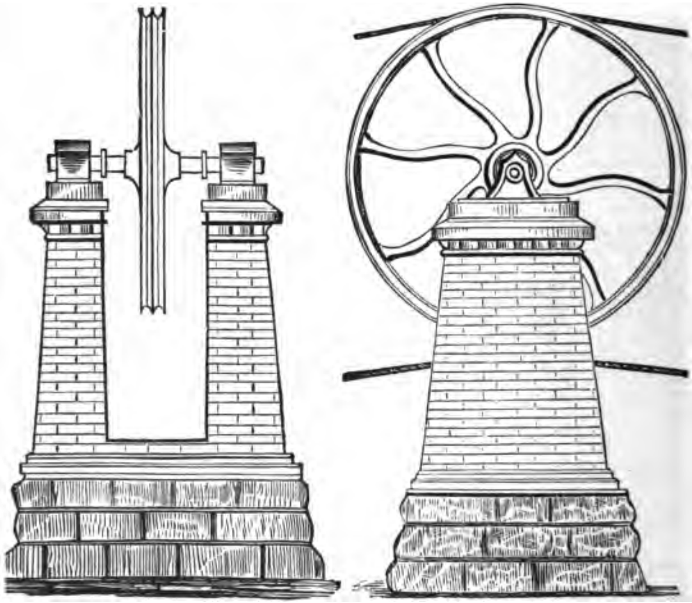
Speed.	400 Feet per Min.	800 Feet per Min.	1,200 Feet per Min.	1,600 Feet per Min.	2,000 Feet per Min.	2,400 Feet per Min.	2,800 Feet per Min.	3,200 Feet per Min.	3,600 Feet per Min.	4,000 Feet per Min.	5,000 Feet per Min.
Width of Belt.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
4 Inches.	4	8	12	16	20	24	28	32	36	40	50
6 "	6	12	18	24	30	36	42	48	54	60	75
8 "	8	16	24	32	40	48	56	64	72	80	100
10 "	10	20	30	40	50	60	70	80	90	100	125
12 "	12	24	36	48	60	72	84	96	108	120	150
16 "	16	32	48	64	80	96	112	128	144	160	200
20 "	20	40	60	80	100	120	140	160	180	200	250
24 "	24	48	72	96	120	144	168	192	216	240	300
30 "	30	60	90	120	150	180	210	240	270	300	375
36 "	36	72	108	144	180	216	252	288	324	360	450

TRANSMISSION OF POWER BY WIRE ROPE.

The use of wire rope in the transmission of power, instead of long lines of heavy shafting, pillow-blocks, couplings, &c., in cases where the distance between the motor and the work to be performed is unusually great, has become quite popular within the last few years. It is recommended, under favorable circumstances, by the comparatively small cost at which it can be put up and maintained. The wire ropes, (which pass over large sheaves or grooved pulleys at a very high velocity,) are manufactured of iron, steel, or copper, as desired, and always with a hemp centre or core to increase the pliability, their range in

size being small, varying only from $\frac{3}{8}$ to $\frac{7}{8}$ inches diameter for 3 to 300 horse-power. For the smaller powers it is advisable to use a size full large to increase their wearing capacity; but it must be remembered that a large rope is stiffer than a small one, and that more power is lost in bending it around the wheel. A $\frac{7}{8}$ rope having the same velocity as a $\frac{3}{4}$ rope transmits less power, simply because of its greater stiffness.

The wheels should be made of cast iron, accurately balanced, with a stout hub and a deep flaring groove, the depth and width of groove depending much on the length of span, and whether or not the rope be subjected to side winds. The rope must run on a cushion of soft wood, oakum, rubber, or leather; the last two mentioned are best, and are



cut into pieces of proper shape to be driven into and fit the bottom of the groove that has been so made as to prevent the filling from flying out. The rope runs on such a cushion without any noise or slipping whatever, soon fitting a small round groove to itself, and is capable of running usually from two to five years, when a new rope can be supplied at trifling expense.

At the point where belting becomes too long, the wire rope is proper-

ly the transmitting medium, and may be employed even miles in length When, however, the distance materially exceeds 350 or 400 feet, intermediate stations should be erected, mounted by double grooved wheels, by that means dividing a long, continuous, and heavy rope into two or more short endless ropes, extending from one station to another. The stations should be of nearly equal distance apart, but not so near one another as to prevent the proper tension of rope. Single pulleys are, however, now much used for the intermediate stations, and we believe to good advantage, there being but one endless rope in the whole distance. The cuts illustrate the double-grooved pulleys or wheels, mounted on solid masonry; a cheaper design of iron or wood may be used. Special care should be observed in getting the axles and journal-boxes well adjusted, and in having a solid foundation reaching below frost, when the loss of power from friction of journal and air, with the bending of rope also, need not exceed 12 per cent. per mile, while the cost will fall below 7 per cent. of the expense of shafting. Whenever the distance is less than 80 feet, it becomes necessary to stretch the rope very tight, as the sag cannot be depended upon for the required amount of tension; in such cases the rope should be one or two sizes larger, and the maximum velocity maintained. Should the distance exceed 450 feet, with no opportunity for an intermediate station, the rope in this case should also be one size larger than would otherwise be required. In such cases it is also advisable to take up the slack or stretch at the end of two or three months; although the stretch is comparatively little, it is well to have them full tight at first, when, after some running, they will adjust themselves to the necessary tension.

When it can be so arranged, it is advisable to have the upper side of rope the follower or slack-side, and the lower the tight or pulling side. Obstructions may thus be often avoided, besides affording the rope more surface on the groove; but the upper rope should under no circumstance be allowed to become so slack as to swing upon the lower rope. The possibility of such occurrence would be increased by the adoption of small wheels, but should, with ordinary care and watching, give little or no difficulty. As to the size of grooved wheels, where there should a choice occur between a small wheel of high velocity and a large one with a slower speed, the larger one should be preferred, since it both further separates the rope and diminishes the loss of power arising from the more abrupt curvature of the small wheel.

HORSE-POWER OF ENGINES.

To find the horse-power of an engine, multiply the area of the piston in square inches by the average pressure on the piston in pounds per inch; multiply this product by the number of feet of piston travel per revolution, and the product thus obtained by the number of revolutions per minute; divide the last product by 33,000, and the quotient will be the horse-power.

EXAMPLE:—To find the horse-power of an engine with cylinder of 16 inches diameter, 20 inches stroke, 120 revolutions per minute, with average pressure of 40 pounds: 16 inches diameter gives piston area of 201 square inches; 201x40 equals 8,040; this by $3\frac{1}{3}$ ft. (40 inches, being a double stroke) equals 26,800; this by 120 equals 3,216,000, which divided by 33,000 gives 97.454 or about 97 horse-power.

SPEED OF SHAFTING AND SIZE OF PULLEYS.

To find the speed of a countershaft, if the revolutions of the main shaft and size of pulleys are given:—Multiply the revolutions of the main shaft by the diameter in inches of the pulley, and divide by the diameter in inches of the pulley on the countershaft, the quotient will be the number of revolutions.

EXAMPLE:—What will be the speed of a countershaft, with a 12 inch pulley driven by a 30 inch pulley 180 revolutions per minute? 180 x 30 divided by 12 equals 450 revolutions per minute.

To find the size of a pulley required, if the number of revolutions and size of pulley on the main shaft are given:—Multiply the diameter in inches of driving pulley by the revolutions of the main shaft, and divide by the speed required, the quotient will be the diameter in inches of the pulley.

EXAMPLE:—What will be the diameter of a pulley to make a countershaft turn 450 revolutions per minute, driven by a 30 inch pulley 180 revolutions per minute? 180 x 30 divided by 450 equals 12 inch pulley.

To find the size of a pulley for a main shaft if the speed of shafts and diameter of pulley on the countershaft are given:—Multiply the diameter in inches of pulley by speed of the countershaft, and divide by the revolutions of the main shaft, the quotient will be the diameter of the pulley.

EXAMPLE:—What will be the diameter of a pulley, on a main shaft making 180 revolutions per minute, to drive a 12 inch pulley 450 revolutions per minute? 450 x 12 divided by 180 equals 30 inch pulley.

SPEED OF DRUMS AND PULLEYS.

The diameter of the driven being given, to find its number of revolutions.

Multiply the diameter of the driver by number of its revolutions, and divide the product by the diameter of the driven; the quotient will be the number of revolutions of the driven.

The diameter and revolutions of the driver being given, to find the diameter of the driven that shall make any given number of revolutions in the same time.

Multiply the diameter of the driver by its number of revolutions and divide the product by the number of revolutions of the driven; the quotient will be its diameter.

To ascertain the size of the driver.

Multiply the diameter of the driven by the number of revolutions you wish to make, and divide the product by the revolutions of the driver; the quotient will be the diameter of the driver.

In ordering Pulleys, always give the exact size of the shaft on which they are to go, and state how you wish them finished on the face· *Flat* face for shifting belt, *Rounding* for non-shifting belt

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WHEEL GEARING.

TERMS USED, PROPORTIONS AND RULES FOR CALCULATION.

DEFINITION OF TERMS.—(*Haswell.*)

The pitch line of a wheel is the circle upon which the pitch is measured, and it is the circumference by which the diameter, or the velocity of the wheel, is measured.

The Pitch is the arc of the circle of the pitch line, and is determined by the number of the teeth in the wheel.

The True Pitch (Chordial), or that by which the dimensions of the tooth of a wheel are alone determined, is a straight line drawn from the centres of two contiguous teeth upon the pitch line.

The Line of Centres is the line between the centres of two wheels.

The Radius of a wheel is the semi-diameter running to the periphery of a tooth.

The Pitch Radius is the semi-diameter running to the pitch line.

A Mortise Wheel, is a wheel constructed for the reception of teeth or cogs, which are fitted into recesses or sockets upon the face of the wheel.

A wheel which impels another is termed the Spur, Driver or Leader; the one impelled is the Pinion, Driven, or Follower.

A series of wheels in connection with each other is termed a Train.

When two wheels act upon one another, the greater is termed the Wheel, and the lesser the Pinion.

When a pinion is driven by a wheel, the number of teeth in the pinion should not be less than eight.

When a wheel is driven by a pinion, the number of teeth in a pinion should not be less than ten.

The number of teeth in the wheel should not be divisible by the number of teeth in the pinion without a remainder. This is in order to prevent the same teeth coming together so often as to cause an irregular wear of their faces.

PROPORTION OF TEETH OF WHEELS.--(*Molesworth*).

From pitch line to top of tooth....equals the Pitch multiplied by 0.33
Total depth of teeth..............equals the Pitch multiplied by 0.75
Thickness of tooth on pitch line...equals the Pitch multiplied by 0.45

Space between teeth on pitch line..equals the Pitch multiplied by 0.55
Thickness of rim of wheel.........equals the Pitch multiplied by 0.45
Thickness of arms if flat..........equals the Pitch multipiled by 0.45
Ordinary width of teeth in small pitches..............................
................................equals the Pitch multiplied by 2.
Ordinary width of teeth in large pitches...........................
................................equals the Pitch multiplied by 3.
Thickness round centre............equals the Pitch multiplied by 1.3

Mortise wheels to be wider than iron wheels by twice the thickness of the rim, or by pitch x 0.9; their rim to be double the thickness of that of iron wheels.

RULES OF CALCULATION—(*Haswell.*)

TO COMPUTE THE NUMBER OF TEETH OF A WHEEL FOR A GIVEN DIAMETER AND PITCH.

RULE.—Divide the diameter by the pitch, and opposite to the quotient in the table on page 185 is given the number of teeth.

TO COMPUTE THE NUMBER OF TEETH IN A PINION OR FOLLOWER TO HAVE A GIVEN VELOCITY.

RULE.—Multiply the velocity of the driver by its number of teeth, and divide the product by the velocity of the driven.

Example.—The velocity of a driver is 16 revolutions, the number of its teeth 54, and the velocity of the pinion is 48; what is the number of its teeth?

16 multiplied by 54 and the product divided by 48 equals 18 teeth.

2. A wheel having 75 teeth is making 16 revolutions per minute; what is the number of teeth required in the pinion to make 24 revolutions in the same time?

16 multiplied by 75 and the product divided by 24 equals 50 teeth.

TO COMPUTE THE DIAMETER OF A WHEEL FOR A GIVEN PITCH AND NUMBER OF TEETH.

RULE.—Multiply the diameter in the table on page 185 for the number of teeth by the pitch, and the product will give the diameter at the pitch circle.

Example.—What is the diameter of a wheel to contain 48 teeth of 2.5 ins. pitch?

15.29 multiplied by 2.5 equals 38.225 ins.

TO COMPUTE THE PITCH OF A WHEEL FOR A GIVEN DIAMETER AND NUMBER OF TEETH.

RULE.—Divide the diameter of the wheel by the diameter in the table on page 185 for the number of teeth, and the quotient will give the pitch.

Example.—What is the pitch of a wheel when the diameter of it is 50.94 inches, and the number of its teeth 80?

50.94 divided by 25.47 equals 2 inches.

PITCH OF WHEELS.—*Haswell.*)

Showing the diameter of a Wheel for a given Pitch, or a Pitch for a given Diameter.

No. of Teeth.	Diameter in Inches.	No. of Teeth.	Diameter in Inches.	No. of Teeth.	Diameter in Inches.	No. of Teeth.	Diameter in Inches.
8	2.61	45	14.33	82	26.11	119	37.88
9	2.93	46	14.65	83	26.43	120	38.2
10	3.24	47	14.97	84	26.74	121	38.52
11	3.55	48	15.29	85	27.06	122	38.84
12	3.86	49	15.61	86	27.38	123	39.16
13	4.18	50	15.93	87	27.7	124	39.47
14	4.49	51	16.24	88	28.03	125	39.79
15	4.81	52	16.56	89	28.33	126	40.11
16	5.12	53	16.88	90	28.65	127	40.43
17	5.44	54	17.2	91	28.97	128	40.75
18	5.76	55	17.52	92	29.29	129	41.07
19	6.07	56	17.8	93	29.61	130	41.38
20	6.39	57	18.15	94	29.93	131	41.7
21	6.71	58	18.47	95	30.24	132	42.02
22	7.03	59	18.79	96	30.56	133	42.35
23	7.34	60	19.11	97	30.88	134	42.66
24	7.66	61	19.42	98	31.2	135	42.98
25	7.98	62	19.74	99	31.52	136	43.29
26	8.3	63	20.06	100	31.84	137	43.61
27	8.61	64	20.38	101	32.15	138	43.93
28	8.93	65	20.7	102	32.47	139	44.25
29	9.25	66	21.02	103	32.79	140	44.57
30	9.57	67	21.33	104	33.11	141	44.88
31	9.88	68	21.65	105	33.43	142	45.2
32	10.2	69	21.97	106	33.74	143	45.52
33	10.52	70	22.29	107	34.06	144	45.84
34	10.84	71	22.61	108	34.38	145	46.16
35	11.16	72	22.92	109	34.7	146	46.48
36	11.47	73	23.24	110	35.02	147	46.79
37	11.79	74	23.56	111	35.34	148	47.11
38	12.11	75	23.88	112	35.65	149	47.43
39	12.43	76	24.2	113	35.97	150	47.75
40	12.74	77	24.52	114	36.29	151	48.07
41	13.06	78	24.83	115	36.61	152	48.39
42	13.38	79	25.15	116	36.93	153	48.7
43	13.7	80	25.47	117	37.25	154	49.02
44	14.02	81	25.79	118	37.56	155	49.35

NOTE.—The pitch in this table is the *true pitch*, as before described.

TEETH OF WHEELS—CAST-IRON.—(*Molesworth.*)

Table showing the horse-power that may be transmitted by each inch of breadth of tooth, with different velocities and pitches:

Veloc. in Feet per Second.	Pitch of Teeth in Inches.										
	3/4 H. P.	1 H. P.	1 1/4 H. P.	1 1/2 H. P.	1 3/4 H. P.	2 H. P.	2 1/2 H. P.	3 H. P.	4 H. P.	5 H. P.	6 H. P.
1/4	.008	.015	.023	.033	.045	.06	.093	.135	.24	.37	.54
1/2	.017	.03	.047	.67	.09	.12	.18	.27	.43	.75	1.08
3/4	.025	.045	.07	.101	.138	.18	.281	.4	.72	1.12	1.62
1	.033	.06	.094	.135	.184	.24	.375	.54	.96	1.5	2.16
2	.067	.12	.188	.27	.366	.48	.75	1.08	1.9	3.0	4.3
3	.10	.18	.28	.40	.55	.72	1.1	1.6	2.8	4.5	6.4
4	.13	.24	.37	.54	.73	.96	1.5	2.1	3.8	6.	8.6
5	.17	.30	.47	.67	.91	1.2	1.8	2.7	4.8	7.5	10.8
6	.20	.36	.56	.81	1.1	1.4	2.2	3.2	5.7	9.	12.9
7	.23	.42	.65	.94	1.28	1.68	2.6	3.7	6.7	10.5	15.1
8	.27	.48	.75	1.1	1.4	1.9	3.	4.3	7.6	12.	17.2
9	.30	.54	.84	1.2	1.6	2.1	3.3	4.8	8.6	13.5	19.4
10	.33	.6	.94	1.35	1.8	2.4	3.7	5.4	9.6	15.	21.6
12	.40	.72	1.1	1.6	2.1	2.8	4.5	6.4	11.5	18.	25.9
14	.47	.84	1.3	1.8	2.5	3.3	5.2	7.5	13.4	21.	30.2
16	.54	.96	1.5	2.1	2.9	3.8	6.	8.6	15.3	24.	34.5
18	.61	1.1	1.7	2.4	3.3	4.3	6.7	9.7	17.3	27.	38.9
20	.66	1.2	1.9	2.7	3.6	4.8	7.5	10.8	19.2	30.	43.2
22	.74	1.3	2.1	2.9	4.	5.3	8.2	11.9	21.1	33.	47.5
24	.81	1.4	2.2	3.2	4.4	5.7	9.	12.9	23.	36.	51.8
26	.88	1.5	2.4	3.5	4.7	6.2	9.7	14.	24.9	39.	56.1
28	.95	1.6	2.6	3.7	5.1	6.7	10.5	15.1	26.9	42.	60.4
30	1.01	1.8	2.8	4.	5.5	7.2	11.2	16.2	28.8	45.	64.8
35	1.2	2.1	3.3	4.7	6.4	8.4	13.1	18.9	33.6	52.5	75.6
40	1.3	2.4	3.7	5.4	7.3	9.6	15.	21.6	38.4	60.	86.4

Pitch of equivalent strength for the teeth of wheels in different materials:

Pitch for Cast iron equals 1,00.
" Brass " 1,12.
" Hard Wood " 1.25.

DIAMETERS OF JOURNALS OF "FIRST MOVERS."

The following table, derived from the experiments of Mr. Robert Buchanan, gives the required diameter of journals of driving shafts or "first movers," for a range of 4 to 60 horse power and 10 to 105 revolutions per minute:

No. of H. P.	Number of Revolutions per Minute.																			
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
	Diameter of Shaft in Inches.																			
4	5.5	4.8	4.5	4.	3.7	3.8	3.5	3.3	3.2	3.1	3.	2.9	2.9	2.8	2.7	2.7	2.6	2.6	2.6	2.5
5	5.9	5.1	4.7	4.4	4.1	3.9	3.7	3.6	3.5	3.3	3.3	3.2	3.1	3.	3.	2.9	2.9	2.8	2.8	2.7
6	6.3	5.5	5.	4.6	4.4	4.1	4.	3.8	3.7	3.6	3.5	3.5	3.4	3.3	3.2	3.2	3.	3.	2.9	2.9
7	6.6	5.8	5.2	4.9	4.6	4.4	4.2	4.	3.9	3.7	3.6	3.6	3.5	3.4	3.4	3.3	3.3	3.2	3.1	3.1
8	6.9	6.	5.5	5.1	4.8	4.6	4.4	4.2	4.1	4.	3.9	3.8	3.7	3.6	3.5	3.5	3.4	3.4	3.3	3.2
9	7.2	6.3	5.7	5.5	5.	4.8	4.5	4.4	4.2	4.1	4.	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.4	3.3
10	7.4	6.6	5.9	5.6	5.2	4.9	4.7	4.6	4.4	4.2	4.1	4.	3.9	3.8	3.7	3.7	3.6	3.6	3.5	3.4
12	7.9	6.9	6.3	5.8	5.6	5.4	5.2	5.	4.8	4.6	4.4	4.3	4.2	4.1	4.	3.9	3.8	3.8	3.7	3.6
14	8.3	7.2	6.7	6.2	5.9	5.6	5.4	5.2	5.	4.7	4.5	4.4	4.4	4.3	4.2	4.1	4.	4.	3.9	3.8
16	8.7	7.6	7.1	6.6	6.1	5.8	5.6	5.4	5.2	5.	4.8	4.7	4.6	4.5	4.4	4.4	4.3	4.2	4.1	4.
18	9.	7.9	7.5	7.	6.6	6.2	5.8	5.6	5.4	5.2	5.	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.2
20	9.3	8.1	7.7	7.2	6.8	6.4	5.9	5.7	5.6	5.4	5.2	5.1	5.	4.8	4.6	4.6	4.5	4.5	4.4	4.4
25	10.	8.5	8.	7.4	7.1	6.8	6.3	6.	5.9	5.6	5.5	5.4	5.3	5.2	5.1	4.9	4.8	4.7	4.6	4.6
30	10.7	9.3	8.4	7.9	7.4	7.1	6.9	6.7	6.5	6.3	5.9	5.8	5.7	5.6	5.5	5.3	5.2	5.1	5.	4.9
35	11.4	9.8	8.9	8.4	7.9	7.4	7.1	6.9	6.6	6.5	6.3	6.1	5.9	5.7	5.6	5.5	5.4	5.3	5.2	5.2
40	11.7	10.5	9.3	8.8	8.3	7.8	7.4	7.2	6.9	6.7	6.6	6.4	6.2	6.	5.9	5.8	5.7	5.6	5.6	5.5
45	12.	10.6	9.7	9.2	8.7	8.1	7.6	7.4	7.	6.8	6.7	6.5	6.4	6.2	6.1	6.	5.9	5.8	5.7	5.6
50	12.6	11.	10.	9.3	9.	8.5	8.	7.8	7.4	7.3	7.2	6.9	6.8	6.6	6.5	6.4	6.2	6.	5.9	5.8
55	13.4	11.4	10.4	9.8	9.1	8.8	8.4	8.	7.5	7.4	7.3	7.2	7.	6.7	6.6	6.5	6.3	6.2	6.1	6.
60	13.6	12.	10.8	10.	9.3	9.	8.6	8.2	7.7	7.6	7.4	7.3	7.2	6.9	6.8	6.8	6.7	6.6	6.4	6.2

TRAMMING A MILLSTONE.

There are some millers so thoroughly skilled as to be able to tell by the "feel" and appearance of the meal when the runner requires to be

trammed; but as there are comparatively few who can do this, the following method may be employed to ascertain whether the spindle and consequently the runner, is out of tram: Take off the runner and fix a horizontal arm to the spindle head, with a pin or quill projecting down from it just far enough to mark on the bed-stone; then, when the spindle is turned, the pin will show whether it is out of tram and if so, in which direction it varies from the perpendicular. To put it in tram, the followers in the bush may be adjusted, or the step-box moved; or if an improved mill-bush or adjustable step-box is used, the tramming is done by simply turning one or two screws.

TABLE OF TRANSMITTING CAPACITY OF SHAFTING.

[By Samuel Webber, in Leffel News.]

The following table gives the number of horse power which may be safely transmitted by wrought iron shafting, properly supported, at 100 revolutions per minute:

First Movers, Carrying Main Pulley or Gear.		Second Movers, or Line Shafting, 8 Feet Spans.		Third Movers, or Short Counter Shafts, with Bearings near Pulleys.	
Diameter.	Power.	Diameter.	Power.	Diameter.	Power.
1 Inch.	1 H. P.	1 Inch.	2 H. P.	1 Inch.	3 H. P.
1.25 "	1.95 "	1⅛ "	2.85 "	1 1-16 "	3.59 "
1.50 "	3.37 "	1¼ "	3.90 "	1⅛ "	4.27 "
1.75 "	5.36 "	1⅜ "	5.19 "	1 3-16 "	5.02 "
2 "	8. "	1½ "	6.74 "	1¼ "	5.85 "
2.25 "	11.39 "	1⅝ "	8.58 "	1 5-16 "	6.78 "
2.50 "	15.62 "	1¾ "	10.72 "	1⅜ "	7.79 "
2.75 "	20.80 "	1⅞ "	13.18 "	1 7-16 "	8.91 "
3 "	27 "	2 "	16 "	1½ "	10.12 "
3.25 "	34.33 "	2⅛	19.19 "	1 9-16 "	11.19 "
3.50 "	42.87 "	2¼ "	22.78 "	1⅝ "	12.87 "
3.75 "	52.73 "	2⅜ "	26.79 "	1 11-16 "	14.41 "
4 "	64 "	2½ "	31.24 "	1¾ "	16.07 "
4.25 "	76.77 "	2⅝ "	36.17 "	1 13-16 "	17.86 "
4.50 "	91.12 "	2¾ "	41.60 "	1⅞ "	19.77 "
4.75 "	107.17 "	2⅞ "	47.53 "	1 15-16 "	21.81 "
5 "	125 "	3 "	54 "	2 "	24.00 "
5.25 "	144.70 "	3⅛ "	60 92. "	2 1-16 "	26.32 "
5.50 "	166.37 "	3¼ "	68.66 "	2⅛ "	28.78 "
5.75 "	190.11 "	3⅜ "	76.89 "	2 3-16 "	31.40 "
6 "	216 "	3½ "	85.74 "	2¼ "	34.17 "
		3⅝ "	95.27 "	2 5-16 "	37.09 "
		3¾ "	105.46 "	2⅜ "	40.18 "
		3⅞ "	116 37 "	2 7-16 "	43.44 "
		4 "	128 "	2½ "	46.87 "

For other velocities, multiply by the number of revolutions and divide by 100.

UNEVEN EXPANSION OF MILLSTONES.

There is no doubt of the expansion of mill burrs under the heat of grinding; and where the burr blocks are not of even temper or homo-

geneous quality, one will expand more than another, producing unevenness on the face of the burr. When this occurs, it may be remedied by stopping the burrs and immediately, before they have time to cool, applying the red staff, which will show the high points on the stone. These may be dressed off, and when the stone is cold it will be found lower at these points than elsewhere; but when heated by grinding the different degrees of expansion will bring up these low points, and the stone will have, while in operation, a true face, which is the essential point in view.

RULES FOR ASCERTAINING THE LENGTH OF BELTS.

[By W. W. YOUNG, in *Leffel News.*]

To find the length of belting required for any two wheels or pulleys whose sizes and distance apart are known:

For a straight belt for two pulleys of the same size: Add the circumference of one of them to twice the distance between their centers.

For a cross belt for two pulleys of the same size: Add the square of one of their diameters to the square of the distance between their centres, and to twice the square root of this sum add the circumference of one of them.

For a straight belt for pulleys of different sizes: Take the radius of the less from that of the greater pulley; to the square of their difference add the square of the distance between their centres; and to twice the square root of this sum, add half the circumference of each.

For a cross belt for pulleys of different sizes: To half the difference between their diameters add that of the less; to the square of this add the square of the distance between their centers; and to twice the square root of this sum, add half the circumference of each.

These rules will give the exact distance around the pulleys, provided they are not so different in size or so near each other as to cause the belt to touch more than half the circumference of the larger and less than half that of the smaller. In that case a small allowance can be made which would still make the rules sufficiently exact for all ordinary purposes. If a pulley on a horizontal shaft is belted to one on a perpendicular shaft, calculate the length of their belt as a straight belt for parallel shafts and then make allowances for the twist and distance over the idler.

THE TEETH OF SAWS.

The pitch of saw-teeth should vary according to the nature of the wood to be sawed, being greater for soft than for hard wood; and for cross-cutting the teeth should be smaller and more acute, operating like knives upon the wood, while in the rip-saw they should be of larger size and cut more after the manner of a chisel. A rip-saw, whether it

be a hand or a vertical mill-saw, should plow its way through the wood, presenting its teeth like a series of sharp chisels, leaving a groove behind it of the same width as the tooth and cutting or paring the wood into regular shavings rather than fine dust. The front of the tooth should slant forward instead of having a direction at right angles with the back of the saw; the difference resulting in the two cases being that in the one the chips will be cut out clean and smooth and with the least practicable expenditure of power, while in the other the saw will simply be jammed through the wood and scrape out its path with a wasteful outlay of strength on the part of the operator or of the motive power, whatever it may be. Nevertheless, it is declared by the best informed writers upon this subject that in the case of the mill-saw a large majority of those in use are of the objectionable pattern above described; while as regards hand-saws, hardly one in ten has any other than the bruising, scraping, perpendicular tooth.

A very common defect in slitting saws is the slenderness of the teeth at the points, in consequence of which lack of strength they are found to tremble or chatter, especially when considerable force is applied to the saw. The difference between the strength of teeth shaped like the letters VV and those shaped more nearly thus *LL*, will be perceived upon a moment's examination, the points in the latter case being well backed and supported, while the V shaped tooth has comparatively but little firmness. This principle is recognized in the construction of all rip-saws of modern pattern, whether hand or mill, vertical or circular saws.

It is a well-known fact that a plank is much more easily sawed when the saw-table is raised so that the saw just goes through the plank than when the table is lowered so that the plank meets the saw at or near the center of the latter. The cause of this is obvious; the teeth in the former case move lengthwise with the grain, like a knife when used to whittle a long shaving from a stick; in the latter case the teeth cut the grain nearly at right angles, as when the knife is used to cut square across the stick.

The points of the teeth of slitting-saws should be slightly beveled in order to adapt them to any occasional contact with knots or cross grain. If the stuff were known to be perfectly straight grained the teeth might safely be filed square across; but it is not often that such a certainty exists. The bevel should be greater for hard than for soft wood. Sufficient space must always be allowed between the teeth to admit of the shaving being held and carried through without crowding or choking.

An important point in filing the teeth of either a straight or circular saw is that the teeth should all be given exactly the same length, so that each will do its proper share of the work. The slightest inequality in this respect will produce irregularity in the operation of the saw, one tooth cutting the wood while two or three shorter ones before or after it, although they may be in perfect order, perform no service. On a straight saw the points should be so accurately in line that they will

all touch a straight-edged rule without showing a variation of a hundredth part of an inch. It is the points of the teeth that do the cutting, and if they are of irregular length so that the saw jumps from one long tooth to another and skips two or three short ones between, all the work bestowed on them is thrown away, and the power exerted on the saw is in some measure wasted.

The kein should not be so narrow as to pinch the saw, nor wide enough to allow the blade to rattle when in motion—there being also, in the latter case, a waste of power in cutting out more wood than is necessary. The teeth should be set just sufficiently to permit the saw to work freely—all beyond this will do more harm than good.

Unevenness of the points may be remedied by securing a large flat file to a block of wood in such a way that the extreme points only will be jointed, and all brought into the same precise line or circle, compelling every tooth to do a part of the cutting. The work of setting and filing a saw just as it should be done demands as much skill and dexterity as almost any process in mechanical industry which can be named, inasmuch as a single false thrust with the file may entirely destroy the working power of a tooth.

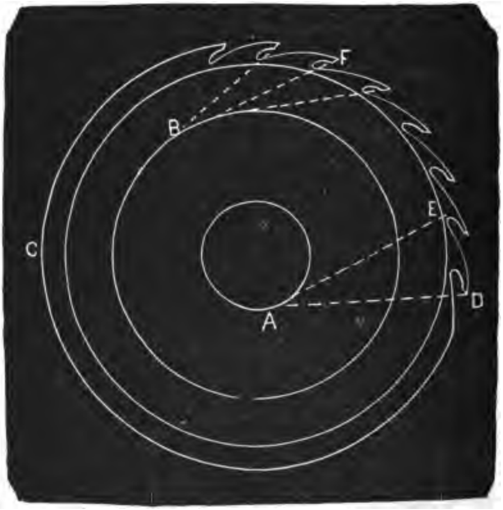
METHODS OF LAYING OFF SAW TEETH.

The following system of laying off saw-teeth is given by a skillful workman as the result of thirty years' experience. For a 50 inch saw, strike a circle A from one-half to two-thirds of the distance from the

eye to the verge. Take a straight edge and lay it at the point of the tooth, the other resting on the circle before drawn, making the line

B C. Gum the tooth with a $\frac{3}{4}$ inch gummer, $\frac{1}{2}$ inch down from the point of the tooth on the line B C; this forms the under side of the tooth. Now take hoop iron formed into a segment of a circle having the same radius as the saw, the chord being equal to the line B C; lay one end of the segment even with the under edge of the tooth (the arch being up) the other end resting on the circle at B. The arch of the segment will form the back or top of the tooth, which is to be kept like the face of a chisel,—the corners being full, so as to cut clear as a mortising chisel. This forms a system easy to be understood, and which may be varied to suit the timber to be sawed, and still retain the uniformity in size and shape of the teeth, which is of great importance. The nearer the circle A is drawn to the verge of the saw, the greater will be the pitch of the teeth. The point at which the circle is to be drawn, which is the first step in the process, would therefore be determined according to the pitch which it is desired to give the teeth to adapt them to their intended work.

Another veteran saw-mill operator describes his method as follows: The shape of the teeth in the following cut is the best I have ever tried



yet. I strike a circle, A, one-fourth from the centre to the verge. I then take a pair of dividers, place one part on the point of a tooth, as at D, and the other part on circle A. After placing the dividers, I slide them from the point D to the throat E of the next tooth, making the line DE, which is the proper circle for the tops of the teeth. I strike another circle, B, three-fourths from the center to the verge. A

straight-edge BF from that circle gives very near the right shape for one-fourth of an inch of the points of the fronts of the teeth. I gum saws with a grind-stone. I turn it down to three-fourths of an inch thick at the outer edge, and taper it gradually towards the centre. I grind inside of the line BF from circle B to the points of the teeth, for the reason that it can be filed so much quicker. I am not guided by the line on the front of the teeth altogether. I generally file them as thin as they will stand and not crumble off at the point. I do not spring set any. I swage to the gauge on both sides of every tooth. Saws dressed in this manner will cut from 3,000 to 4,500 feet of hard wood with the bark on and right out of the Missouri river, all sand and grit, and 5,000 to 6,500 feet of cottonwood with one filing.

STRAIGHTENING CIRCULAR SAWS.

The main causes of spring in saws are, undue heating, uneven cooling, inferior steel, improper gumming and swaging, or general incompetency upon the part of the operator.

Circular saws are rendered especially inefficient by being warped or dished. The warping or kinking consists in local expansion or contraction, and the remedy is the relief of the tension at one part, or the creation of tension at another. To do this successfully requires rare judgment and considerable skill upon the part of the workman. Some skillful straighteners have been known to remedy the evil at a single light blow. In no case are the blows delivered to be hard enough to leave an indentation or impression upon the saw blade or plate. They are made, not with a view to giving the metal a permanent set, but, as before suggested, to remove or create tension.

The tools employed for straightening, are, 1, a "doghead" hammer, that is, one having the helve well back from the body of the rounded-faced hammer-head; 2, a blocking hammer, adapted to making blows, which, if visible, would resemble the lines shown thus on the saw plate; 3, a straightening block or anvil of iron, with smooth, bright and slightly rounded face; and 4, a wooden block for straightening the finished saw.

Of course the greater tension is upon the concave side of the blade, for it is this tension that causes the blade to bend in that direction. To relieve this contraction the blade is laid flat upon the anvil, concave side up, and with the doghead hammer, slow, firm, solid blows are struck upon the warped place, the hammer being so manipulated that the least possible rebound of the hammer takes place. Such blows stretch the concave portion and relieve the tension at that point.

To straighten out warps or kinks by blows on the convex side of the blade, the blocking hammer is used, the convex side being upward on the anvil and the operator striking even, steady blows at proper intervals on the surface of the blade. This latter method is usually employed in taking bends or local kinks out of hand or straight-saws.

When a circular saw is dished, or evenly concave, the doghead hammer must be used at proper intervals throughout the entire concave surface of the saw. The saw is finally tested by bending it, by sighting it, or by applying a straight-edge to its surface. A slight tension should be left on the outer diameter of every circular saw, to allow for the expansion which always takes place at that part through the centrifugal motion of the saw.

If the saw is badly warped, and the workman is not a skilled mechanic, the services of a regular saw manufacturer should be called into requisition, as more harm than good may be done by unskillful treatment of the saw.

HANGING, FILING AND SETTING CIRCULAR SAWS.

First examine your collars, using a straight edge to see that no fash has been raised around the pin-holes, or other obstructions to prevent the collars biting upon the outer edge when screwed up. See that the mandrel is firm in its boxes, and not too tight to heat in running, or has too much lateral motion. Place the saw upon the mandrel, the flat side next to the log. When the saw does not run perfectly true it may be remedied by packing thin letter paper between it and the fixed collar. When this is accomplished, adjust the mandrel so that when the front teeth touch the log the back teeth are set off a sufficient distance to clear themselves. This "pitch" will ordinarily be scant 1-16 inch in a 56 to 60 inch saw. Joint or round off your saw, so that each tooth will do its proportion of work. The most expeditious mode of doing this, is to hold a piece of grindstone (placed upon something stationary) against the teeth while the saw is running, or by attaching a file to the end of a piece of scantling while the saw is turned backward, either by hand or power.

SHARPENING CIRCULAR SAWS.

The following method is recommended for sharpening a circular saw which has become blunted. The saw being set in motion, a fine cut file is held against the teeth until all are equally leveled. A pointed tool or steel pen, dipped in ink, is then applied to the saw as it revolves, a little below the depth of the teeth, making a circle on the saw plate. The saw is then taken from the spindle and either remounted or screwed into a bench-vise between two washers of wood, which should reach within half an inch of the teeth. The teeth are then carefully filed to the line drawn with the tool or pen.

THE THEORY AND PRACTICE OF BALANCING A MILLSTONE.

It should first be remarked that a stone should never be put in balance under a less speed than is counted working speed when grinding.

The first thing to be done is to get out two boa
inches wide and ½ or ¾ of an inch thick. Light
enough to allow the boards to be slipped und
boards, one on each side of the spindle, about
the spindle and the skirt of the stone. Their po
following cut, in which are represented the u

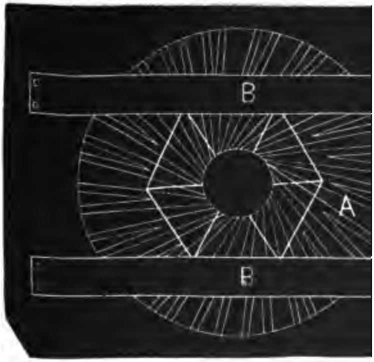


Fig. 1.

boards B B, of their proper proportionate length
the boards down at both ends to the husk floor,
and lighter it down until it bears solid on the bo
the runner and make it run true with the face.
over the back of the runner, from which to turn
make it true with the face. Previous to turning
the followers in the bush should be examined an
the spindle steady and prevent any lateral mo
with loose followers. After the runner has bee
boards are to be taken out and the runner start
speed. Hold a pencil against the rest provide
for turning the back, until the pencil touches th
at the outer edge of the stone.

Now stop the stone and see which side the pe
marked side being the one which runs high. If
of the weight of that side happens to be below t
is the cause of the stone running high on that
may be above the level of the cock-eye on th
where the pencil marked; and should that be the
of that side running low, as the line of motion
difference of weight above and below the leve
opposite sides of the stone.

The following cut will give a more distinct idea of the application of this principle:

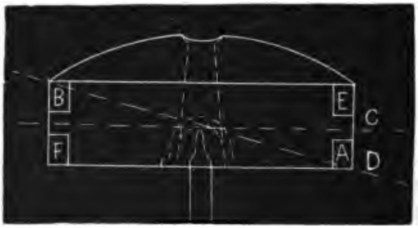


Fig. 2.

Line C would be the line of motion if the stone were in perfect running balance, that line being parallel to the face of the runner. But suppose the stone to be twenty pounds heavier at B than at A—the position of the stone would be so changed by the centrifugal force of this excess of twenty pounds at B that line D would represent the plane of motion, the stone being depressed on one side and elevated on the other, and the face of the runner would be out of level in the same degree as line D. This is an extreme illustration, as the stone would not in any case show so much out of running balance as line D without throwing itself from the cock-head before it could be brought up to motion; but we give an exaggerated view of the case in order to explain the principle more clearly.

To make a stone run true that is out of balance in the manner indicated in the cut, it is necessary to add at E a weight equal to the excess at B—it being supposed, meanwhile, that the weight at F is equal to that at A. If it be supposed, on the other hand, that B and E are equal and the stone out of balance by reason of an excess of weight at A, that excess must be equalized by placing a corresponding weight at F.

There are various methods of ascertaining where the excess of weight is that causes the stone to run out of balance. An expert can generally determine the point by stopping the stone and tipping it by bearing on it with his finger around the edge. Where this cannot be done, take a piece of hoop iron, put it around the stone, and slip bars of lead in behind it at the point where they appear to be needed. Start the stone, ascertain if it runs any more correctly, and continue trying until you have placed the right amount of weight in the right place. Cut into the stone where the lead has been placed behind the hoop-iron, and put in the lead, adding to it the weight of the iron and plaster or stone which has been cut out. Plaster up the hole and try the stone to determine whether it is in perfect running balance, as it should prove to be if the work has been carefully and accurately done.

If the stone is found to be in perfect running balance, stop it and it will immediately show whether it is in standing balance, as the heavy

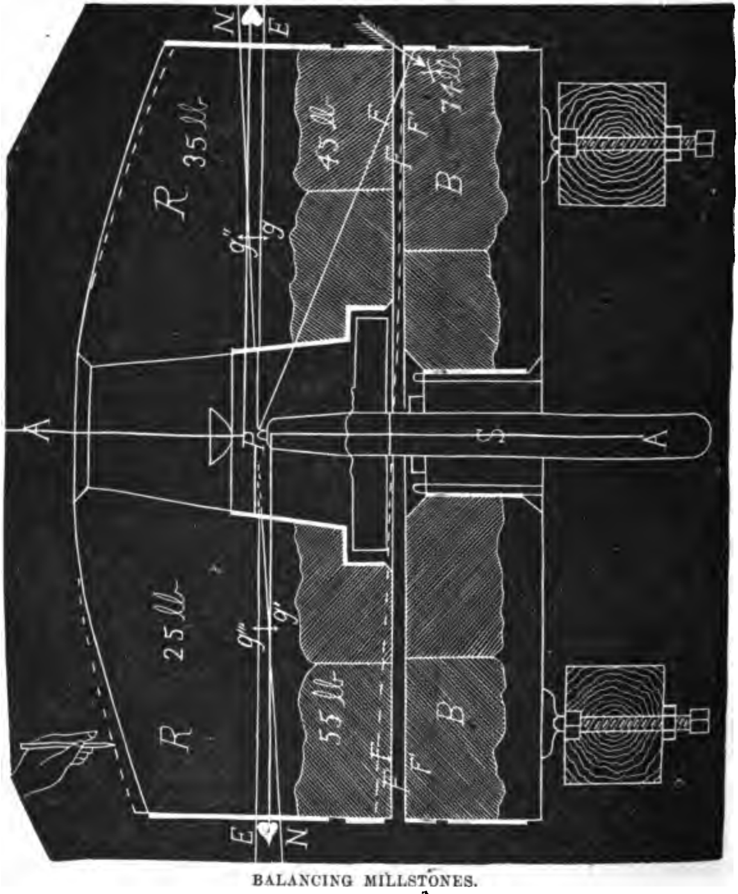
side will go down. It is easy to ascertain, by laying weights on the light side until the heavy side comes up level, exactly how much weight is required to put the stone in standing balance. The question, however, is, where is this weight to be placed in order not to affect the running balance? To determine this, measure the distance from the top of the cock-eye to the face of the stone—then measure the same distance up from the face on the outside of the stone, reaching the point indicated by line C on the diagram. Cut into the side and run in the desired amount of weight to put the stone in standing balance. This weight must be equally divided above and below line C (the level of the cock-eye) or it will disturb the running balance.

Considerable practice is necessary to enable a workman to put a stone in perfect balance, but the foregoing directions will be found reliable as a guide in the process. The bed-stone must of course be level and the spindle in perfect tram, in order to do good work. While the back of the stone is being turned off, it is well to put an old cloth or bag in the eye, to prevent the plaster from getting down round the neck of the spindle. It is also desirable that the surface of contact of the cock-head and cock-eye should not exceed one-fourth of an inch at most, in order that the stone may balance easily.

Valentine Bachman, M. E., in the *Mechanical News*, gives the following analysis of this method: To examine the conditions relative to balancing, and to trace the effects produced by an unbalanced runner, to their cause, we refer to the adjoining figure in which R, R, represents a section of the runner-stone; B, B, a section of the nether stationary or bed-stone; S, the mill-spindle provided at the upper end with a steel-pivot P, upon which the runner-stone is suspended, so as to admit of free oscillation. The distance from the face F, F, of the runner-stone to the pivot P, is found in practice to be from 5 to 8 inches, according to the size of the stone. Since the thickness of the runner-stone varies from 12 to 20 inches, this would bring the center of gravity of the runner-stone below the point of suspension P, a condition favorable to stability, or in other words, the millstone when disturbed, will oscillate until equilibrium is restored. It will not be so easily upset. In order that the runner-stone may be in "balance," or the distance between the face F, F, of the runner-stone and the face F′, F′, of the bed-stone, be equal, when the latter is perfectly horizontal, and the former freely suspended, the weight of the portion of the runner on one side of a line, A, A, drawn through the point of suspension P, and perpendicular to the face F′, F′, must be equal to the corresponding half on the other side of the same line. Should this not be the case, the deficiency is easily made up by cutting a cavity at the light side, near the circumference and filling it with an amount of lead sufficient to establish the proper equilibrium.

Millstones when balanced while at rest, are usually found, when running, not to retain an equal distance between the faces; one side will drag; bear harder on the meal subjected to its action; consequently a millstone in this condition will grind unevenly. It is said to be out of "running balance."

From the very nature of the construction of the French millstone (the kind used at present most exclusively), being an assemblage of blocks, called "burr blocks," of various sizes and on an average about



BALANCING MILLSTONES.

5 inches thick, the remainder of the body of the millstone being made up of spawls, all cemented together with plaster of Paris; it is evident that the material can not easily be distributed symmetrically, as to

weight. To illustrate—conceive a line E, E, drawn through the pivot P, and parallel to the face F, F. We will also suppose a section 6 inches thick cut out of the center of the millstone 4 feet in diameter would weigh about 260 lbs., taking the weight of the plaster at 90 lbs. per cubic foot, and that of the burr block at 160 lbs.

Now it may happen that in the construction of the millstone, 45 lbs. may be placed to the right of the center line A, A, and below the horizontal line E, E; 35 lbs. may come above this line on the same side of A, A,; 55 lbs. and 25 lbs. may chance to be on the opposite, below and above E, E, respectively. The sum of the weights on the right of A, A, is equal to the sum of the weights on the left, viz: 80 lbs. The standing balance still obtains. The center of gravity g, and g' of each half of our section taken separately however, will not be in or at equal distances from the line E, E, with the material thus distributed; but will fall above on the right to g'', and below on the left to g'''; a line joining these centers of gravity will take the direction N, N. Now when a millstone so constructed is rotated about its axis A, A, the center of gravity g''' will rise, and g'' tend to fall. The line N, N, would become nearer horizontal as the speed increases, the line E, E, becomes inclined and the face F, F, untrue. The millstone is out of "Running balance."

The amount of pressure produced in our example assumed, we compute as follows: We draw a line through the center of gravity g'' parallel to the face F, F, until it meets the perpendicular line, A, A,; we similarly draw a line through g'''. We will also suppose the centers of gravity g'' and g''' to be removed $\frac{1}{4}$ of an inch from their proper place on the line E, E. The centrifugal force would be given, by the known expression $\frac{m\ v^2}{r}$ where m, represents the mass, or the weight divided by the force of gravity, in our case for $\frac{1}{2}$ of the section $\frac{80}{32}$ v, is the velocity in this instance, for the point g'' or g''' and in a stone 4 feet in diameter at 175 revolutions per minute, 18 feet per second, about; r, represents the radius, equal to P, g equals 1 ft. in our case. Hence substituting these values in the formula, we obtain $\frac{80.18.18.}{32.1.}$ equals 810 lbs. for the centrifugal force. The part of this force which is effective in producing the pressure at X equals 810. Cosine of the angle EP x equals 734 pounds nearly. The force acts with the lever arms $g\ g''$ equals $\frac{1}{4}$ inch and PX equals 25 inches. We have therefore, for the total pressure at the point X $\frac{734}{4.25} \times 2$ equals 14.68 lbs.; an amount not unfrequently present in millstones in use.

What is required, therefore, to adjust the "Running Balance" without disturbing the "Standing Balance" is to add or remove the same weight from each side. Thus if we add 10 lbs. to the part weighing 25 lbs. and the same amount to the part weighing 45 lbs., we have not disturbed the standing balance, while we have made the weights of the parts above and below the line E, E, equal respectively.

Several patent balances which facilitate the operation have been introduced. A more common one consists of a cast iron box, which is inserted in the stone at the circumference, and in which a weight can be raised or lowered by means of a screw. All that is required in this case, is to find the high point in the manner described; raise the weight at this point, and lower it at the low point, thus taking weight from the upper half of the stone and adding to the lower half, and the reverse.

Some further illustrations of the distinction between standing and running balance, with directions for tramming the spindle into the runner, are given by a practical millwright, as follows:

It is essential that the runner should be hung perfectly in the center, that it should be backed with good calcined plaster, and nicely turned off. If it should then be out of balance, weight it at three equal points on the periphery, taking care to put the weight on a level with the point of the spindle if possible. The reason why a stone may balance when at rest, and not when in motion, may be illustrated as in Fig. 1 representing a stone balanced at rest, but not in running balance as

Fig. 1.

will be seen by Fig. 2, representing the position toward which the same stone will tend when put in motion. When in motion, No. 2 and No. 3 have a tendency to come into a horizontal line with No. 1.

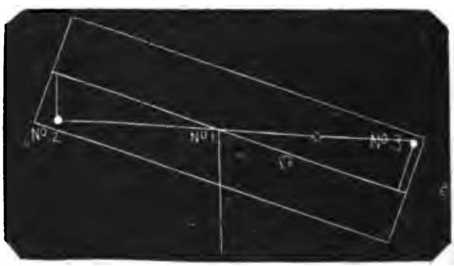


Fig. 2.

It is essential that your drivers have an equal bearing at each end; every spindle should be trammed into the runner before being placed in its final position. To do this, lay your runner off, face up; place the spindle and driver in the eye, in working position; make a tram of a strip of board about eighteen inches long, by making a hole half way through at one end; put this on the step point; take another strip about two feet long, make a half circle at one end that will fit the neck of the spindle, place it near the face of the stone, and connect the two by a strip from one to the other, parallel to the spindle; make a hole at the outer end of the lower piece, after the manner of a common

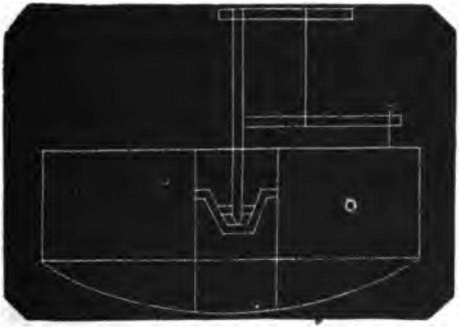


Fig. 3.

tram; turn this round upon the face of the stone, moving the top or step end of the spindle, until it is at right angles with the face of the runner. Then observe whether your driver bears equally at each end; if not, file off until it does. The process described will be clearly understood by an examination of Fig. 3.

TOOL FOR REMOVING SCALE FROM BOILERS.

Various implements are used for removing scale from boilers, a mill-pick, for instance, being frequently employed. In the accompanying cut, however, is illustrated a tool which has been found decidedly preferable to the pick, being expressly adapted to this particular use. It is 4 inches long, and 1¼ inches on cutting edges. There is a cutting edge on each side of the handle, one edge being parallel to the handle, and the other at right angles with it. The weight of the tool is about one pound.

MILLSTONE DRESS.

The following query was presented some time since: "A miller is laying off a dress on a four-foot burr, say 18 quarters, two furrows to the quarter. He steps off the 18 quarters at the skirt and marks; then he draws a circle of 8 inches diameter around the eye, for 4 inches draft. He lays his furrow stick outside of the circle and to mark on the skirt, and draws a line. Does that line represent the feather edge of the furrow or the back?"

Mr. M. N. Elwell, of Oneonta, N. Y., furnishes the following reply and the accompanying diagrams, which fully illustrate his points: If the furrow stick is laid outside the draft—as shown in Fig. 1—to lay

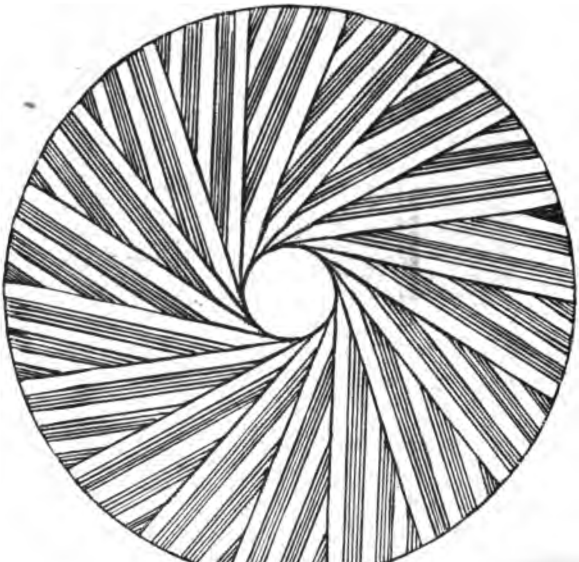


Fig. 1.—MILLSTONE DRESS.

out the main furrows, the line along the side of the stick next to the draft circle represents the feather edge side of furrow, and the line farthest from the draft circle the back or deep side. Then the burr will have the width of these furrows more draft than the draft circle represents. The draft should be measured from the deep side of the furrow.

The correct way to lay out the main furrows is shown in Fig. 2,

which represents a four foot stone, having 4 inches draft, 18 quarters, 3 furrows and 3 lands to each quarter; scale one foot to ¾ of an inch. After deciding how much draft the burr is to have, and the number of

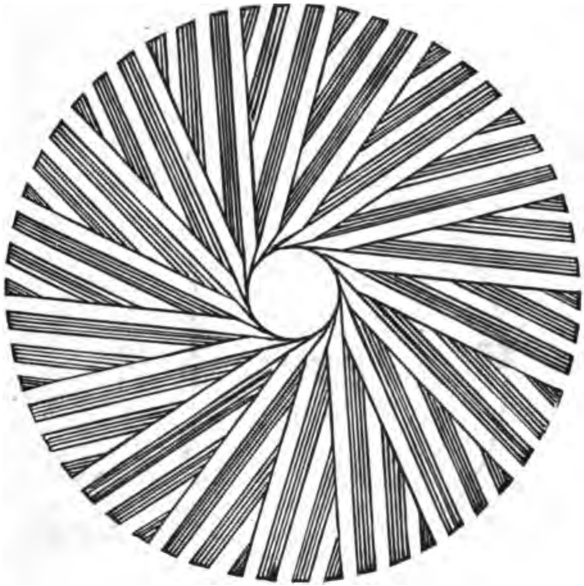


Fig. 2.—MILLSTONE DRESS.

quarters, draw a circle representing that draft, the diameter of which must be twice the draft, whether it be 3 or 4 inches—more or less.

Space off the quarters, around the circumference, marking at each point. Then with a furrow stick made the width you wish the furrows to be, proceed to lay out the furrows by laying one end on the inside of the draft circle, bringing the edge farthest from you to its center, and the other end and same edge of the stick to the center of one of the quarter marks, and mark out the furrow. This brings the deep or back side of the furrow to draft circle, where it should be to give the burr the draft that the circle represents.

LAYING OUT FURROWS IN MILLSTONES.

[By A. P. Fenwick in *Leffel News.*]

In the diagrams, 1, 2 and 3, we are supposed to be unencumbered with eye fittings, such as bush, boxes, and balance rynd. The method

of laying off the furrows with those parts fitted, will be treated further on. In each case we will suppose that the stone is face upwards and level, with a board fitted in the eye, level with the stone face.

The first move is to find the center of the stone on the board. In Fig. 1 is shown the method of finding the center, as far back as I can remember, and may yet answer very well in some instances where small stones are used. We will now suppose we are supplied with a beam-compass, with which to divide the circumference into four equal parts, starting at a given point A^1. These divisions being found, the four points are established at A B, A B, all the same as the given

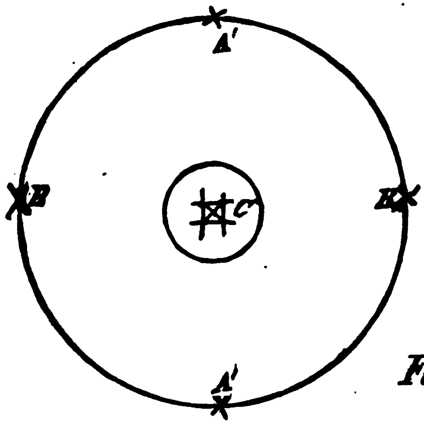


Fig. 1

point at A^1. The beam-compass is now set to reach to within an inch of the center of the stone, one leg resting at one of the quarter points; scribe a short line on the board, and proceed to the other quarter points in turn, till the square in the eye board is complete at C. Lay a rule on the square and draw the diagonal lines from corner to corner as shown. The point where the lines cross is the center from which the draft circle is described. With small compasses the required draft is given, which in most cases is given in inches and half inches, as the stone is feet or half feet in diameter, widening the compasses in inches or half inches, for every foot or half foot of diameter; now complete the draft circle.

In Fig. 2 the operation differs slightly from the operation in Fig. 1, but its importance will be readily understood. The more distant the circumference is from the center, the more important the object becomes to secure the exact center; especially when the fittings are to place or replace, or the position of existing fittings is required. The least departure from the center in such cases. will result in dissatis-

faction both in balancing and grinding. Proceeding at a given point A^1, pick away the plaster from the side of the stone down to the hoop, against which side one leg of the beam-compass will work, and stand square. In this operation the compass points will need to be nearly two inches wider apart, than was used for Fig. 1.

The first lines of bisection are now made, as at C^1, starting at a given point A^1, and from a position directly opposite. At each place where the compass leg is to stand prepare a place for it to set squarely up against the stone, so that when the center is found, it will be the center of the stone proper without including the plaster. A straight edge is laid to where these lines of bisection cross each other, and the

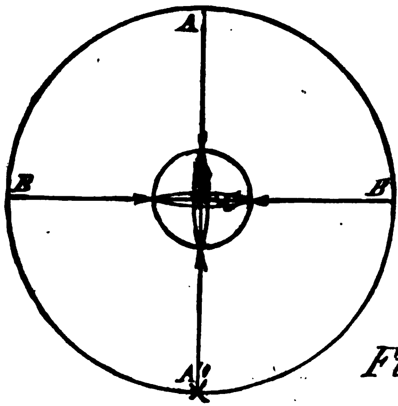


Fig. 2

line *BB* is drawn clear across the stone. The extremities of this line *B B* are the points from which to scribe the other lines of bisection at *C*, through which draw the line *A A* in the same manner as *B B*. Where these lines *A A* and *B B* cross each other, is the exact center of the stone, from which the position of the balance rynd and the boxes may be located, or the position of existing ones ascertained, and the draft circle described.

At Fig. 3 the representations are as follows: *A* the circumference, *B* a circle to space the quarters upon, *C* the eye, *D* the draft circle, *E* the back line of furrow, *F* a given point. We now proceed to space the required number of quarters upon the circle *B*, starting at a given point *F* every time a circuit is made, till the spaces are all equal, and finish up with marking them as shown.

A furrow strip is now laid with one edge as *E* from one of the points on circle *B* to one side of draft circle on the inside. One line only extends to the draft circle, to show the position of the furrow strip in

marking out all the leading furrows; both sides may be lined before removing the strip.

The three furrows shown are called leaders. Mark all the leaders out first, using a strip the same width its whole length. The ordinary width of this strip is $1\frac{3}{8}$ inches. A tapered strip is now required to produce the lands and the rest of the furrows. The dimensions of the tapered land strip given below, will be governed by the width of the $1\frac{3}{8}$ inch furrow strip, because whatever shape or width the furrows may

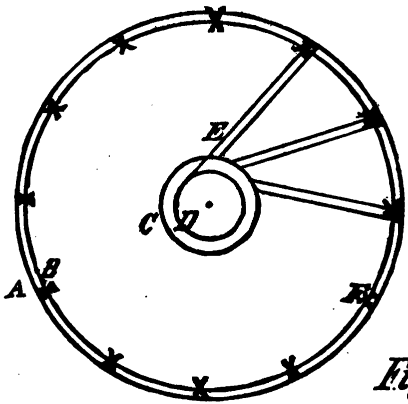


Fig. 3

Fig. 4

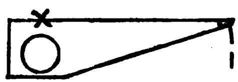


Fig. 5

Scale 1/8 in to the Foot

be required at any future time, may be accomplished by making a furrow strip the desired shape or width, the position for the back edge being then given; that, however, the lands may be increased or diminished, it is accomplished at the feather line or cutting edge. Taper strip measurements:

For $4\frac{1}{2}$ feet stone 22 inches long, wide end $2\frac{3}{8}$ inches
" 4 " " 19 " " " " $2\frac{1}{8}$ "
" $3\frac{1}{2}$ " " 16 " " " " 1 15-16 inches.

In each instance the small end to be $\frac{1}{4}$ inch wide. The land and furrow strip will now follow each other till the other two furrows are

marked beginning with a leading furrow and moving forward, allowing the wide end of the land strip to come just to the edge of the stone each move. The area of space and furrow with this dress will be nearly equal in a twelve quarter dress, three furrows to the quarter.

Fgures 4 and 5 represent a valuable assistant in marking out the leading lines of the leading furrows under any circumstances. It can be used on runner or bed stone, for right or left hand dress, or with the spindle in place or out of place. A hole is made in it to fit the spindle easily, the small end to terminate at the circumference of the size of stone used; a hole is bored near the latter end to admit a pencil, with which to describe the circle *B*. The part Fig. 5, is made to fit the large hole in Fig. 4 tightly, so that the whole can be used to mark the leading lines of runner or bed stone when the eyes are unobstructed, simply by inserting a small iron pin through the center of eye board. The amount of draft required is calculated from the center of spindle hole to the square edge marked thus X. This assistant is best made of a piece of hard, thin, well seasoned board.

The diagram Fig. 3, shows how to lay out the work with the sun; if required to lay out against the sun, turn the assistant over, and commence on the left hand side of the stone.

HOW TO COMPUTE THE CONTENTS OF A HOPPER.

The following rule for computing the contents of a hopper is simple and easy of application, and will be found reliable in practice:

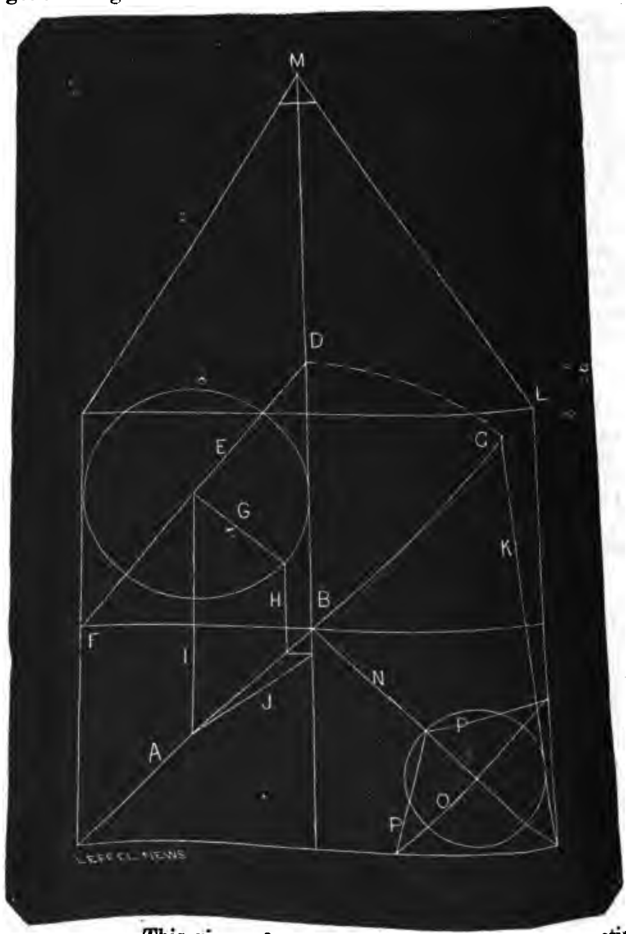
Multiply the length by the breadth, in inches, and this product by one-third of the depth, measuring to the point. Divide the last product by 2,150, (the number of cubic inches in a bushel,) and the quotient thus obtained will be the contents of the hopper in bushels.

VARIOUS METHODS OF SETTING THE BEVELS OF A HOPPER.

The scale of this cut is three-fourths of one inch to one foot, and the hopper 3 feet square on top and 22 inches deep when set together. First strike out the square of the hopper to any scale you wish to work by. Intersect the square both ways in the center, and strike a diagonal as shown at A; scale off on that line from center, B, to C, the depth of hopper. Set your dividers at center, B, and depth of hopper at C, and swing the dividers round until they intersect perpendicular line D. Draw a diagonal line, E, from that point to center line, F. Set your dividers on line F so that by striking a circle they will intersect perpendicular line D and the outside line of the square of hopper; strike a right-angled line, G, from center of line E, until it intersects the circle; then drop a perpendicular line H down to intersect diagonal line A. Carry that line at right angles until it intersects perpendicular line D; then drop a perpendicular line I down to line A, and draw line

J to intersect at line D as shown. It is by lines I and J that you set your bevel square to cut the corners of the hopper by.

To get the length of the sides of corners, strike a line, K, from C to

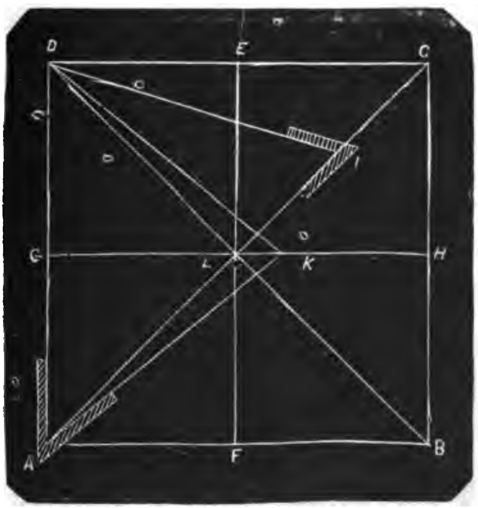


corner of square. This gives the length of line LM, intersecting perpendicular line D; and this determines the width of board required,

from which to make the hopper. You can make any allowance at point M, for hole in hopper, that is thought suitable. To get the corner strip to fit the corners, make diagonal line N, from corner to center. Set your dividers on line N wherever you please, and strike a circle that will just intersect line K. Draw a line, O, through the center of the circle at exactly right angles to line N, until it intersects the two outside lines of hoppers. Draw angular lines PP to intersect the circle on line N. This is where the bevel is set, around lines PP, to get the angle of corner strips. The draft should be carefully and correctly made, and the edges of the boards exactly square where the bevel square is applied to cut the corners. The method here described is applicable for any size, depth or width of hopper required.

ANOTHER METHOD.

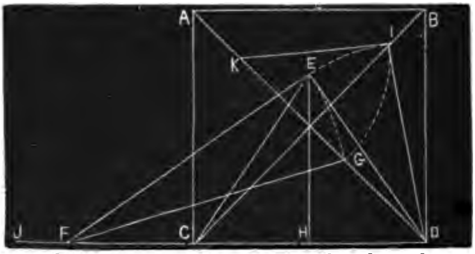
Plat the hopper on a large scale. Draw the diagonals A C and D B, also the perpendiculars E F and G H. From the center L lay off one of the diagonals the distance L I, equal to the vertical depth of the hopper. Connect D I; then with the angle D I A give the bevel to be applied to the edge of the board to cut the required joint between two adjacent sides. Next make D K equal D I, and draw D K and A K.



Then will the angle A D K or K A D give the required bevel to be applied on the *surface* of the board, in order to cut the sides of the proper slope, and give them the proper inclination.

A THIRD METHOD.

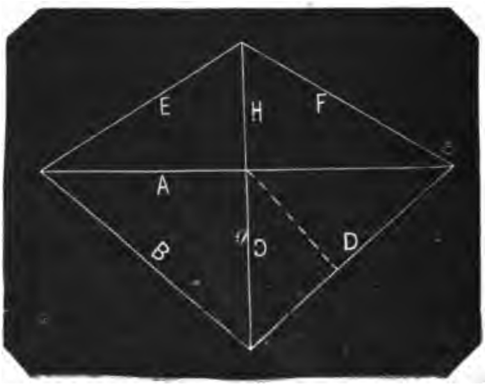
Ascertain the size you want your hopper on the top, then make a draft according to the size, as A, B, C, D. Then find the depth you would have the sides, as H E. Draw one side piece, C E D. Extend the line C D any distance, as to J. Then draw a line from the point E, perpendicular to the line D E, until it intersects C D, say at F. Then set the dividers with one point at E, the other at F, and sweep E G until it strikes the line A D. Now draw the line G F. The angle A G F



would be the angle required to set the bevel for the mitre of a hopper of any size. Then place the bevel to correspond with the lines A G F. To prove it with the dividers or tram, take the distance D E and sweep to I, on a line from B to C. From the point I raise a perpendicular I K to the line A D. Take the distance K I and sweep to G; and if the circle I G and the line F G meet exactly at the point G, the work is right.

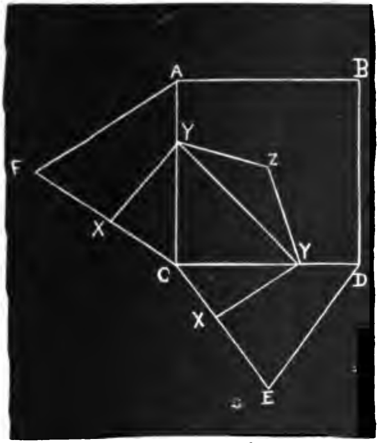
A FOURTH METHOD.

Let the lines A B C D in the diagram represent a hopper 3 feet square on top and 22 inches deep, standing cornerwise to the reader, and



measuring a trifle less than 51 inches across the top. Now measure the distance from center of hopper to one of the corners at right angles with such corner (as shown by dotted line) and lengthen the upright line C just so much, as at H; from which point strike lines E and F to the corners of the hopper. Set your bevel by these lines for corner pieces, and also for joints of hopper, if square joints, or by one of these lines and the upright line H, for mitre joints. The diagram is drawn to a scale of 1 inch to 24.

A FIFTH METHOD.



Let the square A B C D represent the top of the hopper. C D E and C A F the two adjoining sides, of any desired depth. Select the points X X at pleasure, equi-distant from C, and draw the perpendicular X Y. Draw the diagonal Y Y, upon which erect the isosceles tri-angle Y Y Z, making the sides Y Z, equal to XY, the angle Y Z Y being the angle or bevel sought. To demonstrate: Cut the outline of the diagram from a piece of pasteboard; draw the point of a sharp knife along the lines A C and C D; now fold the two adjoining sides so that the lines C F and C E shall join. It will now be seen that the angles Y Y Z and Y Y X are equal, Y Y X being the proper angle delineated upon the side of the hopper.

REMEDIES FOR WEEVIL IN MILLS AND GRANARIES.

It is said that tar is a sure agent for expelling these troublesome insects. An open cask impregnated with tar was placed in a granary thus infested, and in a short time the weevils were seen climbing along the walls in myriads and flying in all directions from the cask. The tarred vessel being moved from place to place, the premises were in a few days completely cleared of the vermin. A few old planks, with their surfaces impregnated with tar (which should be renewed from time to time) will serve the same purpose.

Another method is to wash the walls and floors with boiling water or potash lye, exploring every crack thoroughly with a stiff broom dipped in the lye. Whitewashing the walls, with a thick coat put on while hot, is also recommended, and a further protection is found in covering the windows with fine wire gauze to keep out all insects.

BOLTING CLOTH.

The numbers of bolting cloth in common use range from 000 up to 16, the first mentioned being the coarsest, and the last the finest of the series; and these, as well as the intermediate numbers, are determined by the number of holes or meshes in a given space. The following table gives the number of squares or meshes in each running inch, and also the number in each square inch, for the different numbers of cloth:

No. of Cloth.	Squares per running inch.	Squares per square inch.
000	24	576
00	32	1,024
0	42	1,764
1	52	2,704
2	60	3,600
3	64	4,096
4	68	4,624
5	72	5,184
6	80	6,400
7	88	7,744
8	92	8,464
9	100	10,000
10	110	12,100
11	120	14,400
12	130	16,900
13	140	19,600
14	150	22,500
15	160	25,600
16	170	28,900

The foregoing table may be readily applied and calculated from by the use of the ordinary magnifier or cloth-glass; but as the space included in the field of vision of the glass is only one-fourth of an inch square (one-sixteenth of a square inch) the figures of the second column in the table must be divided by 4, and those of the third column by 16, in order that the number of squares given may correspond with the observation made through the glass. We therefore add, for the convenience of the reader, a table comprising the medium numbers 6, 7, 8 and 9, showing the number of squares which will be counted through the glass; this being sufficient to show how the second table is derived from the first, the same method serving for any of the other descriptions of cloth, whether coarser or finer:

No. of Cloth.	Squares per ¼ running inch.	Squares per 1-16 square in.
6	20	400
7	22	484
8	23	529
9	25	625

The standard and generally received significance of bolting cloth numbers is that given in the foregoing tables; and it is of course desirable that one sole interpretation should be adhered to, in order that the language of the milling business may be uniform, and the seller and purchaser of bolting-cloths be able to understand each other correctly.

The Dufour & Co. bolting-cloth, which has become so famous wherever the manufacture of flour is carried on, is made by the firm whose name it bears, at Thal, in the Swiss canton of St. Gall, and is distinguished for its evenness and roundness of thread, its regularity of texture and the accuracy with which the cloths correspond to their respective numbers. To keep the bolt in good order it is necessary to use occasionally the cloth sweep, made by sewing a breadth of cotton cloth by the edge to a small rope, long enough to reach the whole length of the bolt. This is hung up alongside the reel on the descending side, in such a way that it will drag lightly upon the bolt cloth as it revolves, and remove the beards. As a continual dragging of the sweep will injure the bolt-cloth, and only an occasional application is required, the sweep is so arranged that it can be drawn up or let down at pleasure. When it is first applied after a long interval, the bolt should be run empty for a while, and then carefully shaken down and swept out—otherwise the grist may be spoiled. In some rare cases, as in the event of an accident or very careless treatment of the bolt, it may become necessary to wash the cloth free from accumulations of pasted flour by applying spirits of wine or turpentine freely with a sponge, whipping the cloth smartly but lightly with a small switch as soon as it is perfectly dry. Where the Dutch Anker cloth is used, this operation must be performed with the utmost care, and the spirit used in small quantity, as otherwise the sizing on the threads will be dissolved and destroyed. Where the reel is covered with the English or muslin cloth, no liability exists of injury to the fabric by the application of the spirit.

VERMIN IN BOLTING CLOTHS.

An effectual remedy for vermin in bolting-cloths is an object of earnest search by every miller, and many expedients have been tried. Good results have been obtained by unslipping the burrs, just before stopping the mill for a two or three days' rest, and running at rapid speed until the elevators, conveyors and reels are quite clean or empty. This is done on the theory that the bugs work on the cloth only when the mill is standing, and that they merely cut their way out of the bolt from the inside, and do not eat the silk as moths destroy woolen fabrics.

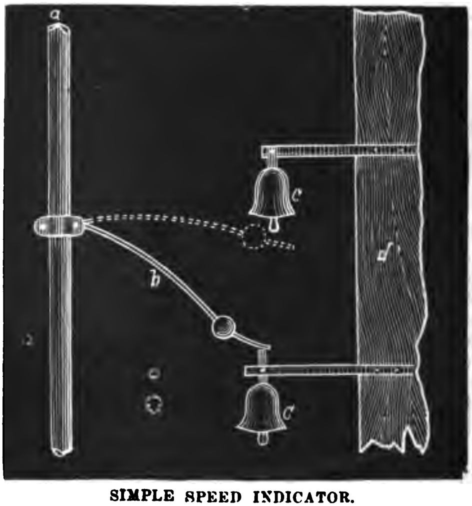
Another method, successfully employed in old mills long infested with bugs, is to cover a reel with wire-cloth of such fineness as not to let the bugs pass through it, and bolt the chop through this just before entering the silk-cloth reel. Not only does this prevent the bugs from gaining an entrance to the reel, but it also keeps out hard substances

which might injure the silk cloth. This method has the advantage of being a preventive rather than a remedy. To keep the bugs out altogether is more satisfactory than any plan which can be devised for expelling them after they have effected a lodgment inside, as they stick very obstinately to the cloth in the neighborhood of the rib until they voluntarily eat their way out. Where this wire-cloth bolt is used before passing the chop into the silk-cloth reel, large quantities of the bugs may be caught by placing a barrel at the end of the wire-bolt, taking care to make the inside of the barrel so smooth that the bugs cannot escape.

The ravages of the bugs may be diminished by making muslin doors to the chest and surrounding it with glass, thus admitting as much light as possible. The most scrupulous cleanliness in all parts of the mill must be observed, whatever else may be done. No dirt or rubbish should be allowed to gather; as it is evident that the uuclean accumulations in a mill not properly cared for are a most fruitful source of vermin—not only bolt-eaters, but all other insects which are bred in a flouring mill.

SIMPLE SPEED INDICATOR FOR MILL SPINDLES.

To the spindle, *a*, fasten a strong wire or rod about 1 foot long in such a manner that it can freely swing perpendicularly. Near the end of this wire tasten a ball about 2 inches in diameter. As the



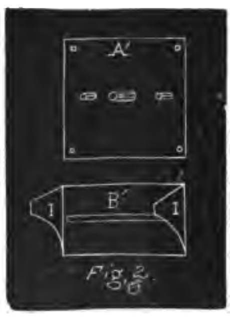
SIMPLE SPEED INDICATOR.

spindle revolves, the ball, of course, rises, and maintains a higher or lower position as the revolutions are increased or decreased.

To a solid post, *d*, two small bells. *c*, *c*, are fastened in such a manner that should the burrs, and consequently the spindle, run too fast, the wire extending beyond the ball will cause the upper bell to ring. Should the revolutions be too slow, the wire will ring the lower bell as shown in the diagram. With this arrangement any miller will be able to regulate permanently the number of revolutions he wishes his burrs to make. For this simple apparatus no extra shafts, pulleys or belts are required. It will be noticed in the diagram, that the lower bell must be made to swing.

USEFUL DEVICE FOR FLOUR ELEVATORS.

Millers are often annoyed by the accumulation of dough in the flour and feed or meal elevators, the quantity becoming so great after a time that the strap and buckets cease to run. Unless the elevators are constructed so as to be easily taken apart, the clearing of them is quite a difficult matter. The accompanying sketches show a device by which this difficulty is overcome.

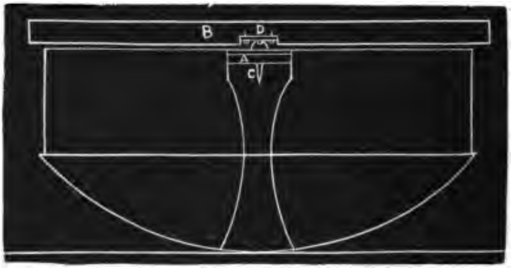


A is a thin plate of iron, the width of the belt, and some 4 or 5 inches long, and fastened to the belt at the four corners by screws or rivets, and upon this plate are three stubs, the center one being the longest and having a thread cut on it for the reception of a thumb-nut.

B is also a thin plate, made the width of the belt, having through its center a slot, and the outer ends, I I. turned up at right angles with the belt D. The edges of this plate are thin and sharp for cutting the dough from the cases. This plate B is made to fit the stubs on plate A, and is held in place by the thumb-screw and nut C, while the slot allows of its being adjusted to one side of the case or the other, as circumstances may demand.

"TRUEING" THE FACE OF A MILL-BURR.

It often happens that the face of a mill-burr is winding in such a manner that the ordinary use of the red-staff in ascertaining the points of inequality does not meet the demands of the case. In such instances a method is adopted of which the following diagram will serve to convey a tolerably distinct idea.

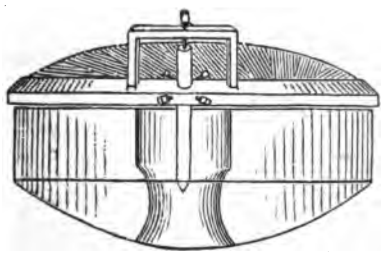


The runner stone is represented in the diagram, and is shown turned over on its back. A is a round piece of wood 1½ or 2 inches thick, and large enough to wedge tightly into the eye. B indicates the red-staff, C a screw inserted in the piece of wood A, and D is a steel plate—a piece of saw-plate answers very well—about ¼ inch thick and 2 inches square, let into the red-staff as shown, and forming, with the head of the screw, which must be nicely rounded off, the pivotal bearing upon which the staff rests. The staff will turn and oscillate with the greatest freedom, being hung after the manner of the magnetic needle in a compass.

To find the places at which the face of the stone is "in wind," the red-staff is tapped with the finger and the manner of its vibration against the stone is closely observed. To do this intelligently and interpret the rattling or "wabbling" of the staff requires a practiced hand. We can hardly convey, in fact, either by words or drawings, to a person entirely unskilled, a clear understanding of the process; but it will be readily comprehended by an experienced workman without such minute explanation. The cut will serve to show how the apparatus is arranged, and the rest must depend mainly on the judgment of the operator.

When the position of a high point is detected by the irregular vibration of the staff when tapped with the finger, the staff is taken off and applied on that part of the stone in the usual manner, the points where the red appears dressed down, and the staff again balanced on the head of the screw, which can be turned down gradually as the stone approaches a perfectly true face; and this process is repeated as long as the staff vibrates irregularly in any direction. When it is found to have a perfectly even and solid contact with the stone, wherever it may be tapped or in whichever direction it may be turned, the face of the stone may be considered absolutely true, and "out of wind," or as nearly so as mechanical skill can make it.

Another method, recommended by a practical miller, is as follows: My plan is to have a short spindle, say 18 inches long by 1½ inches in diameter secured in the eye of the stone as above described, letting it come above the face say 8 inches, to be trammed as near as the winding face will admit. Now take a staff of the usual form, bore a hole in the center say 3 inches in diameter; now fix a bale on the back, and directly over the hole. (This may be done either by bending a strip of band iron, or framing two posts on either side of the hole and fixing a cap on top of the posts.) Put a set screw in the cap directly over the hole in the staff, to rest on the top of the spindle, to raise and lower the staff with. Now fix in the staff 3 or 4 set screws in such shape as to set against the spindle to answer as followers. Paint the staff, put it on the spindle, turn up the set screws so as to touch the spindle, and by means of the screw in the bale let the staff down to the stone. Turn the staff around; the paint in the stone will tell you where to dress off. Continue the operation of staffing and dressing until it paints all around, and your stone will be out of wind. It will not require an experienced workman to work the staff or take the stone out of wind.



In the sketch (showing staff, spindle and stone) the stone is represented as if cut down through the middle, showing the interior of the eye.

DEFECTIVE COCK-HEADS—THEIR RESULTS AND HOW TO RECTIFY THEM.

[By A. Forrest in *Leffel News.*]

One of the most disastrous causes of unsatisfactory work on the part of millstones in use, is defective cock-heads. In the cock-head mill, it becomes most essential that the cock-head and eye should be as perfect as possible, to accomplish its design. The cock-head should be so made that it affords a fixed point of suspension for the stone, as well as allowing it to oscillate freely, and neither of these conditions should be disturbed while the stone is doing its work. I have figured several forms of cock-heads which I have seen in actual use, and some

Fig. 2.

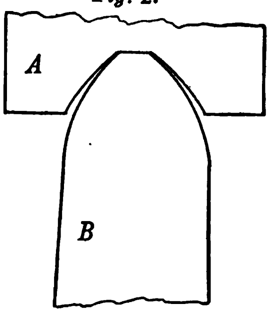


Fig. 3.

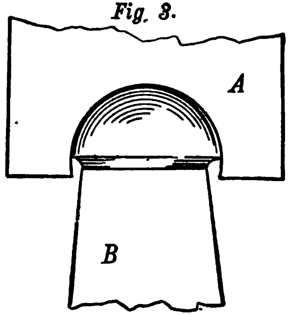


Fig. 4.

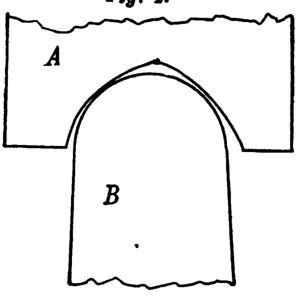
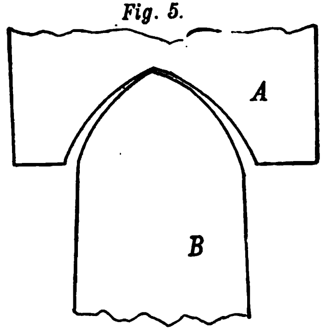


Fig. 5.



MILLSTONE COCK-HEADS.

of them were made in very pretentious shops. I might make drawings of hundreds equally defective, but the cases presented are sufficient to call attention to the subject.

Fig. 2, exhibits a very common form, and anyone can see at once, that when the pressure of the stone is partially relieved, by the grain passing between the stones, the point of oscillation becomes very uncertain. Fig. 5, shows still another form, in which the point of oscillation is more accurately defined, but is subject to same objection, while in use, as the first, and is sure, in a little while, to assume the form shown in Fig. 2, as the point will become blunt by wear. Fig. 4, shows a most fatal form, and yet quite common, fitting none of the conditions mentioned above. No stone can be kept in either *running* or *standing* balance on such a cock-head in such a cock-eye.

Fig. 3, exhibits what I deem to be the proper form, if the utmost care is had in its making. The bearing portion of this cock-head is in form of half of a sphere accurately defined, and the eye is made to correspond with it, both being perfect. The eye should be cherried out to a depth exceeding the half sphere of the cock-head, by at least ⅛ of an inch, as shown in the cut; the body of the cock-head being reduced, leaving the half spherical form full and complete, and thus allowing the stone to oscillate without binding. Now, it will readily be seen, that in case the grain passing between the stones should, not only relieve the whole pressure of the stone upon the cock-head, but actually lift it up to the extent of ⅛ of an inch, the firm pivotal bearing would be maintained, and the stone held firmly to its central position until it settled back to its place. I think any one will see the practical philosophy of this form of cock-head.

This is apparently a trifling matter, yet to just such defects in cock-heads as I have described, may be attributed much of the trouble millers experience with their burrs. I do know that I have completely remedied the unsatisfactory performance of a number of burrs, by simply remodeling the cock-heads upon which they were suspended. Let me say to millers. that when they can not accurately balance their burrs, nor keep them in balance when grinding, first look for the cause in defective cock-heads.

STANDARD WEIGHTS OF GRAIN AND SEED PER BUSHEL.

Wheat	60	lbs.	Clover Seed	62	lbs.
Rye	56	"	Timothy Seed	45	"
Shelled Corn	56	"	Flax Seed	56	"
Ear Corn	68 & 70	"	Hemp Seed	44	"
Corn Meal	50	"	Millet Seed	50	"
Oats	33	"	Hungarian Seed	50	"
Barley	48	"	Blue Grass Seed	14	"
Peas	60	"	Canary Seed	60	"
Beans	60	"	Hominy	60	"
Potatoes	60	"	Bran and Shorts	25	"

DEVICE FOR HOLDING SACKS.

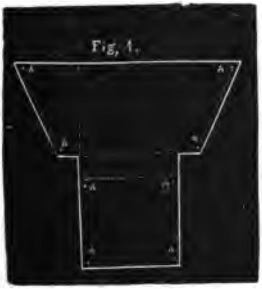
A device for holding sacks or bags upon a spout to catch the meal, flour or bran, is here illustrated. The essential feature of the arrangement is the use of the slipping-brakes, the position of which relatively to the sack A and spout B, (the upper part of which is indicated by dotted lines) will be readily seen in the sketch. The blocks are about 6 inches long and 1 inch square, and may be raised or lowered to any position desired according to the length of the sack; the manner in which the cords pass through them giving, in whatever position, a hold upon them which prevents the cords from slipping, so long as they are drawn tight by any weight from below.

CHEAP AND SIMPLE ELEVATOR BUCKETS.

In the sketch herewith given is shown a wooden elevator bucket which can be easily made, of any desirable size, and at very trifling cost. Scantling 2½ by 3½ inches will serve as the material. The buckets should be made of soft wood and fastened to the belt by two or more wood screws passing through the belt and into the top of the buckets, which should be left thick enough to receive them. The back, or side next to the belt, is beveled a little under square, so as to give the point of the bucket a slight elevation. Buckets thus made, and placed on the belt 18 inches apart, have been found to elevate easily 25 bushels of meal or flour per hour, provided the belt runs the proper speed.

An elevator bucket made of untanned leather is shown in the two succeeding cuts. The raw-hide must first be limed and the hair taken off, and the bucket is then to be cut and made while the leather is soft and pliable. Figure 1 shows the shape in which the leather is to be cut; the letters A A indicating where the punch holes for rivets are to be made, and the dotted lines indicating where the

leather is to be folded to form the bucket. In putting together, the buckets will require four rivets each, two of which are to be $\frac{3}{8}$ inch in length, and two $\frac{1}{2}$ inch. First put in the $\frac{3}{8}$ rivets at the bottom, as at A in Fig. 2, and rivet them; then punch the belt so that the holes will



come in line with the upper holes in bucket, forming the bucket and fastening it to the belt with the same rivets, using the $\frac{1}{2}$ inch rivets for the purpose. Buckets made in this way have been found very lasting and serviceable.

TO SEPARATE LIGHT WHEAT FROM GOOD.

The following method is recommended: Take lye from wood ashes, strong enough to bear up a potato, and having poured the grain into it, skim off all that floats, and pour off the lye. The grain may then be rinsed, and spread out so that it will dry quickly, when it will be in fit condition for sowing. Not only is the light weight thus removed, but insects or their eggs which may be mixed with the grain are destroyed, and no injury is caused to the grain if it is not allowed to remain in the lye. For lighter grains than wheat, lye of less strength is used.

CEMENT FOR MILLSTONES.

The following has been recommended by a French chemist as a good cement for millstones: Oxychloride of magnesium is known to be a hydraulic cement of great strength and hardness. This cement is the basis of an artificial burrstone, and is formed by adding a solution of chloride of magnesium of the proper strength, and in the proper proportions, to the oxide of magnesium obtained by calcining magnesite. The magnesite is burned in an ordinary limekiln at a dark cherry-red heat. The result is protoxide of magnesium, which is next ground to a fine powder, making a cement which is perfectly white. This cement is then mixed with pulverized burr-stone in proper proportions. When

applied in filling the joints or cavities of millstones it is wetted with chloride of magnesium, which converts the oxide of magnesium into oxychloride. The chemical result is due to the combination of the chloride with the oxide of magnesium. It is said that when made into blocks of stone it is capable of resisting a crushing weight of more than 20,000 pounds to the square inch. There is another method of making a millstone cement which has been tested and acts very well. Take 4 ounces of No. 4 emery, 4 ounces gypsum (plaster of Paris) and 4 ounces of alum. Heat hot until the alum is melted. Mix the plaster in water to the consistency of cream; put all the ingredients in a vessel and heat until the alum is melted; stir well or the emery will not mix well. To prepare the stone where you want to put the cement, take a pint of rain-water and dissolve in it as much sal ammoniac as the water will hold in solution; then clean out the cavity to be filled and wash well with the sal ammoniac water and you will never have to fill up that cavity again. In one instance the eye of the stone all scaled and crumbled off and this cement was used, and it held the bush as good as ever. It is strongly recommended by those who have used it.

Millstone cement made of alum and borax for mending broken joints in burrs, is often burnt in melting, thus making a poor job. If the same ingredients, pounded up, are melted by hot water in a glue pot, a good joint may be obtained.

RE-BACKING MILLSTONES.

The processes employed in building millstones at the factory, although interesting in their nature to all engaged in the manufacture of flour, do not immediately concern the practical miller, except so far as he may have occasion to use the same methods in the care and management of his mill. The process of putting a back upon the upper or running stone is one with which it is sometimes necessary for the miller, or at all events the millwright, to be sufficiently acquainted to enable him to perform the task; and it is, moreover, one of those things which if not done properly might nearly as well be left undone. It may be said, indeed, that this is true of almost all branches of the work of a mill; for it would be difficult to point out an item which can be slighted in the least particular without direct damage to the business, either in the amount or quality of the product of the mill.

As the most expedient position in which to handle the burr, no better course can be followed than to let it rest upon the spindle-head, as in this case it can be filled more evenly and brought, when finished, more nearly to a perfect standing balance, than is possible when the stone is laid upon the floor or other similar support. When ready to receive the back, the stone is supposed to be otherwise in complete order—with the exception, of course, of the final process of putting it in running and standing balance. The starting-hoop, which is of iron, should be about 1½ inches wide, and the space between its lower edge and the

face of the stone about ¾ of an inch. Between the starting-hoop and the band a space of about 1 inch should occur, and the band, also of iron, should be about 11 inches in width. The entire depth of a stone, including the filling and plaster back, should be from 18 to 24 inches; the former being suitable for a 3 or 3½ ft. and the latter for a 4½ ft. burr. In the case we are supposing, however, which is that of putting a new back upon an old stone, the sizes, proportions and arrangement of the hoop and band will be already fixed, and are presumed not to require any alteration.

Having taken out the old back, the spawls or fragments of burr-stone removed are to be thoroughly cleaned and all the old plaster adhering to them got rid of before they are again used. The upper surface of the burr-blocks composing the stone is also to be scraped clean; and both this surface and the spawls should be dampened before introducing the plaster. The preparation of the plaster is the next step; and in this part of the work an excellent method is to mix the plaster with alum water—as much alum being used as the water will take up in standing five or six hours. Prepared in this manner. the plaster will set harder than if simply mixed with water, and the back will of course be all the more durable. The plaster when put in should be quite thin, as it will harden with great rapidity, and it must penetrate every part of the back and thoroughly unite with the spawls, before it "sets" in order to give the work the necessary compactness and strength.

The back having been filled to such a hight as the workman may deem suitable, the concluding process is turning it off, which may be done with an ordinary carpenter's chisel, a rest being fixed up for the purpose. It is desirable that the back should be made perfectly true and even, as otherwise, even if the stone is actually in running balance it will have an appearance of unevenness or "wabbling" when put in motion. We have known an expert millwright to turn off the back of a millstone with such unerring accuracy that when running the eye could scarcely detect the motion.

It is frequently necessary to renew a part, but not the whole back of the stone, in which case, the cut having been made and the requisite amount taken out, holes should be made slanting downward and outward in every direction from the main cavity. The necessity for these arises from the fact that the new plaster will not reliably unite with or adhere to the old, and the slanting holes are intended to serve as anchors or roots, so to speak. holding the mass of new plaster down firmly in its place. The holes should be thoroughly cleaned out and the dust made in drilling them removed, after which the cavity is dampened in every part and the plaster poured in and forced down as compactly as possible.

The importance of a firm and durable back on a millstone is well understood by every miller. Cases have been known in which pieces of a back which had crumbled or broken loose have been thrown violently off by the revolutions of the stone, causing great injury, and

even loss of life. Against results of this character it is impossible to take too great precaution, especially when a moderate amount of care and watchfulness is all that is required.

CAUSES AND PREVENTION OF FLOUR MILL EXPLOSIONS.

The principle cause of explosions in flour-mills is held by Valentine Bachman (Polytechnic Review) to be the large quantities of finely-divided dust floating about in the mill, which becomes ignited in presence of lights or fire. The chances for an explosion of flour-dust may be increased by the presence of marsh-gas or olefiant gas, generated from quantities of dust undergoing decomposition. In mills operating under the "new process," the conditions for an explosion obtain more easily. In the old way of milling, the grain was ground very fine in the first operation; nearly all the flour could be obtained, leaving very little for a subsequent grinding. In the "new process," the object is simply to granulate the graiu in the first grinding, or crushing, making as little flour as possible. The coarse particles, or middlings, thus obtained, after being separated from the flour and coarse bran are mixed with fine specks or bran. For the purpose of separating these specks from the middlings, they are together subjected to the action of a machine (middlings purifier) and a current of air, which carries with it the fine particles of bran or specks, leaving the middlings pure and white, fit for the best flour. The specks, dust and air, the latter having become very dry (any moisture being retained by the middlings), are blown into a dust-room, where most of the dust is deposited, while the air escapes outside of the mill or chamber. We have, therefore, in this dust-chamber fine particles of dust in abundance, and dry air under a pressure, conditions favorable for an explosion. Besides, by allowing the dust to accumulate in the chamber, decomposition may take place and explosive gases may be generated, making the mill or dust-house as dangerous as a powder-magazine.

If the dust-houses are made of sheet iron on all but one side, and the remaining side constructed of light material and so located as to be a part of the side of the mill, the danger of a destructive explosion will be greatly reduced. The material for dust-spouts, especially those from all stones, should be sheet-iron, and the end away from the dust-house should pass through the wall of the mill and be covered with light material. The construction of the flour and middlings elevators and spouts should be such as to prevent air-draughts through them, and the conveying of materials by fans should also be avoided as far as possible. An open light should never be used, under any circumstances, in any part of the mill, neither should a light be struck, even to light a lantern, where any dust is present. If it is necessary to introduce a light where a draught of air may bring dust in contact with it, as in a spout or bin, first close one end of the spout; or better still, substitute for the ordinary lantern a light covered with very fine wire gauze. Regulate the supply of feed to the burrs so that they shall not run empty

and strike sparks. If the exhaust-boxes, dust and smut-rooms are located outside of the mill, and care is taken that they are cleaned only when the mill is not running, or that the connection is such that in case of explosion the flame will not be readily communicated to the dust within the mill, the liability of disaster will be much diminished.

The plan of blowing steam into the dust-room of the flouring mill, at suitable intervals, has been suggested, as a remedy for explosions, thus preventing too dry an atmosphere, and causing the particles of dust to coalesce and fall to the floor. Want of sufficient ventilation is also believed to be one of the causes of explosions, on the theory that the gases generated by the steam around the burrs inside the hoops accumulate and form an element of the explosive composition. The method proposed for counteracting this tendency is to run a large box ventilator from the stone-floor to top of mill, with openings into it from each floor, and spouts connecting the dust-rooms and middlings bins with the main trunk of the ventilator. The natural draft through such a ventilator will, it is claimed, carry off the finest dust and the explosive gases, and thus remove the principal source of danger.

REMEDY FOR MUSTY SMELL IN GRAIN.

A musty smell may be removed from grain by mixing powdered coal with it and letting it stand for fourteen days, at the end of which time the coal dust is removed by the purifying machine. This treatment is said to remove every trace of mould, and the flour made is excellent. This process is only practicable in mild weather, and not during a time of frost. Another method may be employed with oats. Put a layer from 3 to 4 inches thick in a baking oven in which bread has just been baked; leave the door and flue open, and stir it about for ten or fifteen minutes until it is well aired and dried.

HOW TO JUDGE GOOD GRINDING.

Catch your hand full of meal as it falls from the stones, and feel it lightly between your fingers and thumb; and if it feels smooth and not oily or clammy, and will not stick much to the hand, it shows it to be fine enough, and the stones to be sharp. If there be no lumps to be felt larger than the rest, but all of one fineness, it shows the stones to be well faced, and the furrows not to have too much draught, as none has escaped unground. If the meal feels very smooth and oily, and sticks much to the hand, it shows it to be too low ground, hard pressed and the stones dull. But if it feels part oily and part coarse and lumpy and will stick much to the hand, it shows that the stones have too much feed; or, that they are dull, and badly faced, or have some furrows that have too much draught, or are too deep, or perhaps too steep at the back edge, as part has escaped unground, and part too much pressed and low. Catch your hand full, and holding the palm up, shut it

briskly; if the greatest quantity of the meal fly out and escape between your fingers, it shows it to be in a fine and lively state, the stones sharp, the bran thin and that it will bolt well. But the greater the quantity that stays in the hand, the more faulty is the flour. Catch a handful of meal in a sieve, and sift the meal clean out of the bran; then feel it, and if it feels soft and springing and elastic, and also feels thin, with but little sticking, to the inside of the bran, and no pieces found much thicker than the rest, the stones are shown to be sharp, and the grinding well done, but if it is broad and stiff, and the inside white, it is a sure sign that the stones are dull or overfed. If you find some parts that are much thicker and harder than the rest such as half or quarter grains, it shows that there are some furrows that have too much draught; or are too deep or steep at the back edge; else that you are grinding with less feed than the depth of the furrows and velocity of the stone will bear.

The foregoing are Oliver Evans' rules for judging the quality of the grinding, and may fairly be regarded as "old, but good." Another practical miller tests the meal by catching a handful and pressing the thumb slowly down upon it. If it settles together like the unsteady packing of snow, the grinding is all right.

TO PREVENT CLOGGING OF MIDDLINGS.

A device which has been employed with success to prevent the clogging of middlings, consists of a simple rod of wood placed inside the eye and extending to the balance rynd. The rotary motion of the rod separates the middlings and prevents clogging, the same device being equally effective if extended into the feeding spout.

REGULATING THE MILLSTONE DRIVER.

The directions given by an experienced miller are: First level the bed-stone, put down your runner, tie a rope to it at a point equal to the hight of the cock-head, turn the stone round until the driver stands north and south, then fasten the rope to a post, put on a portion of your power; now hoist the runner till it clears the bed-stone. The runner can now be rocked north and south, or with the driver, and will stay about as you put it, but east and west, or across the driver, it is stubborn, according to the amount of power attached. Take a sheet of paper, tear it in two, fold each piece, slip one under each side of the stone, east and west, and let your runner down until one of the papers becomes tight; this shows the low side of the stone as it would be when running. Now move the foot of the spindle until both papers are tight, letting down the stone as you move the spindle. When both papers become alike, the stones face exactly together. Then shut off your power. turn the stone just half round, tie again; then if the faces come exactly together when reversed, all is right with the driver, and

with the spindle east and west. Then shut off the power, release it from its cable, turn ¼ round, tie as before: now tram spindle north and south, always keeping the papers at points crossing the driver.

When the first trial is made, and one paper becomes tight first, then if you will reverse your stone without moving the foot of spindle, if the driver be wrong the paper on the opposite side will be tight.

AVERAGE PRICE OF WHEAT FOR TWENTY-NINE YEARS.

The following table, prepared by Messrs. Warder & Barnett, millers, Springfield, Ohio, from records carefully kept by them, shows the average price of wheat, as indicated by purchases made at their mill, from 1852 to 1880 inclusive—a period of 29 years.

Average price in	1852,	63	cents per bushel.
" " "	1853,	82	" " "
" " "	1854,	$1.43	" " "
" " "	1855,	1.57	" " "
" " "	1856,	1.04	" " "
" " "	1857,	1.00	" " "
" " "	1858,	74	" " "
" " "	1859,	1.09	" " "
" " "	1860,	1.04	" " "
" " "	1861,	80	" " "
" " "	1862,	83	" " "
" " "	1863,	1.06	" " "
" " "	1864,	1.50	" " "
" " "	1865,	1.50	" " "
" " "	1866,	2.15	" " "
" " "	1867,	2.41	" " "
" " "	1868,	2.05	" " "
" " "	1869,	1.16	" " "
" " "	1870,	1.06	" " "
" " "	1871,	1.24	" " "
" " "	1872,	1.48	" " "
" " "	1873,	1.44	" " "
" " "	1874,	1.21	" " "
" " "	1875,	1.22	" " "
" " "	1876,	1.23	" " "
" " "	1877,	1.38	" " "
" " "	1878,	1.00	" " "
" " "	1879,	1.05	" " "
" " "	1880,	1.08	" " "

The prices named are for merchantable red wheat, mostly Mediterranean.

The lowest price reached during the twenty-nine years covered by these statistics was 56 cts. per bushel, in August, 1852; the highest, $3.10 per bushel, in May, 1867.

SETTING UP AND RUNNING STEAM PUMPS.

The Dean Pump Works, of Indianapolis, give the following valuable hints on the management of steam pumps:

Never use a smaller pipe on the suction than the list indicates.

Avoid right angles in the pipe, where it is possible.

Where it is practicable, make bends with a large radius.

Put a foot valve and strainer on the end of the suction pipe.

Do not place the pump more than 29 feet from the water.

Where hot water is pumped, the supply must be above the pump.

Make all joints in the suction pipe tight.

A small leak in the suction is very detrimental.

Keep the stuffing boxes nicely packed.

Oil the pump before starting it, and keep the oil wiped off where it is not needed.

Some engineers seem to think that if their boilers are supplied with water there is no need of looking after the pump, or taking any care of it. A good pump is as worthy of being taken care of as a good engine, and we would suggest to all engineers and persons using or having charge of pumps, that they spend a few moments every day in cleaning them up, removing all extra oil on them, wiping off the dust and dirt, and seeing that they are in good condition and working well

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USEFUL HINTS TO FIREMEN.

The English Boiler Insurance and Steam Power Company issues the following instructions to engine firemen:

Water gauges should be blown out frequently during the day, and the glasses and passages to the gauges kept clean. More accidents are due to inattention to water gauges than to all other causes put together.

Safety valves should be tried at least once a day to make sure that they will act freely. Overloading or neglect of these valves tends to the most disastrous results, and can not be too carefully guarded against.

Pressure gauges, where fitted with cocks, should be tried occasionally by shutting off the steam and letting the pointer run back to zero. For this purpose the gauge should be arranged to open to the atmosphere when shut off from the boiler.

Blow-off cocks should be taken apart, examined, and greased when the boiler is cleaned. Make certain that no water is escaping from the blow-off when the cock is supposed to be closed.

Check-valves, or self-acting feed valves, should be taken out and examined when the boiler is cleaned. Satisfy yourself frequently that the valve is acting when the feed pump is at work.

Fusible plugs should be examined when the boiler is cleaned, and carefully scraped clean on both the water and fire sides. If this not done the plug will not act.

To save coal, keep the boiler clean inside and outside. If there is a

plentiful supply of steam, keep a thick fire; but if short of steam, work with a thin fire, keeping the bars evenly covered. Firing a furnace on each side alternately tends to prevent smoke.

To preserve the boiler, raise the steam slowly. Never light fires till the water shows in the gauge glass. Never empty under pressure; but allow the boiler and brickwork to cool before running the water off. Clean the boiler inside regularly once a month, oftener if the water be bad. Clean all flues once a month, stop any leakages, and get rid of any damp in the seatings or covering. Examine especially plates subject to the direct action of fire, the underside of the boiler, and any parts in contact with the brickwork, or with copper or brass, where water is present. If not required for some time, and it is impracticable to empty and thoroughly dry it, fill the boiler quite full with water, and put in a quantity of common washing soda.

Should the water get too low, draw fires at once as a rule; but if the fire is very heavy, or if the furnace crown appears to be red-hot, it is best to smother the fire with wet ashes, wet slack, or any earth that may be at hand. The dampers may then be closed. If the engine is running, or the feed pumps delivering into the boiler, do not stop them; but if not working, do not start them, and do not attempt to blow off the steam until the fire is out, and the over-heated plates have cooled.

PAINTING MACHINERY.

Great lack of taste is often displayed in painting machinery, which is too often daubed with the most glaring and ill-contrasted colors that disgust the sight and mar the general appearance of the machine. The following remarks will assist our readers to a better comprehension of what we mean, and also to select proper artistic contrasts. We have seen machinery in which bright, gaudy reds and scarlets mingled with bright blues and yellows in the most extraordinary way. A very little consideration will show that such combinations are breaches of harmony, which require that one color shall be subservient to the other, so as to pleasantly blend the whole to an even and pleasing tone. Thus, the complementaries of red, are green; of blue, orange; of yellow, violet. Precise rules, however, can not be laid down, and much depends upon artistic effect to be decided by the reasoning eye. The following suggestions as to contrasts, however, may be found of assistance:

I. Black and warm brown,
II. Violet and pale green.
III. Violet and light rose color.
IV. Deep blue and golden brown.
V. Chocolate and bright blue.
VI. Deep red and gray.
VII. Maroon and warm green.
VIII. Deep blue and pink.
IX. Chocolate and pea-green.
X. Maroon and deep blue,
XI. Claret and buff.
XII. Black and warm green.
XIII. Slate color with nearly all bright colors excepting blues.
XIV. Buff and black.
XV. Buff and blue or mauve, and so on.

CHOOSING OAK TIMBER.

Being very hard in texture, oak is peculiarly adapted for all purposes where great strength and durability are required; while its color, which when new is a deep red or light brown, and when old a dark brown, adapts it for all descriptions of household furniture, pannelling, and cabinet work. When applied to the latter purposes it is generally carved, for which its closeness of grain peculiarly adapts it; but this is often a work of great trouble, on account of the hard knots which run through it. In the selection of oak a great deal depends on a knowledge of the soil on which it has been grown, for we generally find that when the product of a peculiarily rich soil it is deficient in strength, being full of sap, which necessarily impairs the solidity of the wood. Again, we have to consider the effects which the atmosphere produces upon it in the situation in which it is grown, as it has been found that even the product of a few acres may vary in quality according to the position of the trees; thus, those having a northerly aspect have been uniformly better in quality than those exposed to the rays of the noonday sun. The best means of discovering the comparative quality of different kinds of oak consists in immersing several specimens in water, and attentively watching the respective weights of each after having been soaked for a certain time; the specimen that has imbibed the least quantity of the fluid should always be chosen for use, as that may be depended upon as being closest in grain, and, consequently, least liable to decay. Those trees which have been cut down in winter should always, when possible, be selected, for in such the sap has become partially dry, and, consequently, they require less seasoning. Great attention should always be paid to the state of the timber about to be selected, examining well the central parts, as there it is that decay generally first shows itself. It is to a want of proper attention to this point that many disastrous accidents may be ascribed, with regard to the beams employed for supporting roofs, etc., breaking beneath their loads.

SELECTING TIMBERS.

Rankine says that there are certain appearances characteristic of good wood to what class soever it belongs. In the same species of wood, that specimen will in general be the strongest and the most durable which has grown the slowest, as shown by the narrowness of the annular rings. The cellular tissue, as seen in the medullary rays (when visible), should be hard and compact. The vascular or fibrous tissue should adhere firmly together, and should show no wooliness at a freshly cut surface; nor should it clog the teeth of the saw with loose fibers. If the wood is colored, darkness of color is in general a sign of strength and durability. The freshly cut surface of the wood should be firm and shining, and should have somewhat of a translucent appearance. In wood of a given species, the heavier specimens are in

general the stronger and the more lasting. Among resinous woods, those which have the least resin in their pores, and, among non-resinous woods, those which have least sap or gum in them, are in general the strongest and most lasting. Timber should be free from such blemishes as "clefts," or cracks radiating from the center; "cup shakes," or cracks which partially separate one layer from another; "upsets," where the fibers have been crippled by compression; "wind galls," or wounds in a layer of wood, which have been covered and concealed by the growth of subsequent layers over them; and hollow or spongy places in the center or elsewhere, indicating the commencement of decay.

TESTING FLOUR ADULTERATIONS.

Dr. Himly, Professor of Chemistry, at the University of Kiel, has suggested a method by means of which any person of ordinary intelligence may test the amount of adulteration of flour. It is based upon the fact that chloroform is specifically lighter than nearly all the substances usually employed for these adulterations, such as lime, chalk barytes, plaster, marble, bone-powder, etc., while the genuine flour is again lighter than chloroform, in which none of the above-named substances are soluble. The testing process is of the simplest, and all the apparatus required is a small test tube about ⅜-inch in diameter and 4 or 5 inches long. A teaspoonful of the flour to be tested is placed in the test glass and chloroform poured on to fill the vessel to about three-quarters of its length, when it is well shaken, and then placed in an upright position, so as to remain undisturbed until the various substances mixed together have had time to find the level assigned them by their specific gravity, the flour swimming near the surface at the top of the vessel, while the mineral bodies will sink to the bottom. It should be observed that unadulterated flour will often show a slight filmy deposit of a greyish or brownish color, which it must be supposed is stone dust produced in grinding. A white deposit, however, will invariably indicate an adulteration with one or another of the substances mentioned above. If the materials are weighed before and after separation, the amount or degree of adulteration may be pretty accurately ascertained.

CALENDER ROLLS.

Paper calender rolls are almost as hard as iron, but are used in preference to iron because, while they will preserve their roundness, truth and smoothness, they possess a certain amount of elasticity, and are therefore less liable to damage from the strain due to any foreign substance passing through them. The method of fixing the paper to the roll is as follows: Disks of thin common brown paper, of a diameter large enough to turn up to the required diameter of roll, and

with a hole in the center of each large enough for them to pass freely over the roller shaft, are first cut out; then a number of similar disks, with the central hole about 4 or 6 inches larger; are made. In putting these disks upon the roll shaft, four having the smaller holes are put on, and then one with the large hole, the object being to insure that the paper shall press together at and towards the outer diameter of the roll, and not bind so tightly towards the center—and thus the outer part of the roll is sure to be the most compact and therefore the most durable.

To avoid bending the roll shaft by reason of any unevenness in the thickness of one side of the sheet of paper from which the disks are cut, every other disk is turned half-way around when placed upon the shaft. When the latter is filled with these disks, it is placed under a very powerful hydraulic press, giving a pressure of about 200 tons, which compresses the disks solid together without the aid of glue or any other adhesive substance. The disks are allowed to stand until they are compressed sufficiently to give room for additional disks, which are added in the same manner as before, the whole being again compressed. This process is continued until the intended length of the roller is filled with compound paper, when the latter is fastened—this, with the locking and finishing, completing the operation.

CONDITIONS INJURIOUS TO SIGHT.

Prof. Raux mentions the following: (1.) Air vitiated by animal emanation, vegetable or mineral dust, the smoke of various combustibles, especially that of tobacco, in which nicotine exists. (2.) Temperature too high or too low, and sudden changes or draughts. (3.) Clothing too tight particularly the neck or waist. (4.) Position with the head and body too much bent forward during labor with the eyes. (5.) Premature study, excess of reading, etc. (6.) Alcoholic excesses. (7.) Use of the eyes and brain immediately after eating. (8.) Habitual constipation, cold feet, and everything which tends to produce congestion of the head. (9.) Immorality, especially during childhood and youth. We might assign a cause still more potent than any of the foregoing, viz: a deficiency of light.

HOW TO PUT AN ENGINE IN LINE.

[BY STEPHEN ROPER, IN LEFFEL NEWS.]

An engine is in line when the axis of the cylinder, and the piston rod are in one and the same straight line in all positions. This line extended should intersect the axis of the engine shaft, and be at right angles to it. The guides should also be parallel thereto. The shaft must be level, but the center line of the cylinder may be level, inclined, or vertical according to the design of the engine.

To "line up" an engine, as it is generally termed, take off the cylinder head, remove the piston, crosshead, and connecting rod, then with a center punch make four (4) marks in the counter-bore at each end of the cylinder at equal distances apart around the bore. Take a piece of stiff hoop iron with a hole at one end of it, slip it on to one of the stud-bolts of the back cylinder head, and secure it firmly with a nut, after which it may be bent in the shape of a crank, one end projecting across the cylinder at its center, at a sufficient distance from it to admit of convenient and accurate measurement. Next draw a fine line through the cylinder, and attach one end of it to the temporary crank above mentioned, and the other end to a stake driven into the floor at the back end of the bed-plate. Then with a piece of hard wood or stiff wire pointed at each end and equal in length to half the diameter of the cylinder, set the line, so that, when one point of the wood or wire is inserted in any one of the center-punch marks at either end of the cylinder, the other end will feel the line. Next see if this line passes through the center of the shaft; if so, the cylinder is in line with the shaft; if not, one or the other must be moved, which requires both skill and judgment, since engines differ so much in design and construction. Now turn the engine shaft round till the crank-pin almost touches the line passing through the center of the cylinder, then ascertain by measurement whether the line is equi-distant from the collars on the crank-pin. Then turn the shaft on the other center until the crank-pin feels the line. If the measures correspond the shaft is in line with the cylinder; if not they will show which end needs to be moved. The operation may have to be gone over several times before a definite conclusion can be arrived at. The shaft may be leveled by placing a spirit level on it, if there be room; if not, drop a plumb-line passing through the center of the crank-pin and shaft; then by placing the crank at both centers and at half-stroke, the line will show whether the shaft is level or not. The guides may be brought into line with the cylinder by measuring from each end of each guide, to the line passing through the center of the cylinder, and moving them until they are parallel to the line and to each other. To adjust them to the horizontal, a spirit-level may be placed on their top faces; if no level is at hand a square and plumb-line may be used; where these accessories are not at hand a straight edge placed across them will determine by actual measurement whether they are in line with the center line of the cylinder or not.

Engines get out of line from the following causes: faults of design, faults of construction, overwork, the character of the work which they are performing, or from the loss of the crank wearing away the face of the main bearing against which it revolves. To move an engine shaft and pillow-blocks into line with the center of the cylinder, screw down the caps of the pillow-blocks firmly on the shaft, then slack up on the bolts that tie down the pillow-blocks to the bed-plate, after which the shaft, pillow-blocks and fly-wheel may be moved from the back end by means of a lever or jack-screw, after which they should be firmly tied,

and the set screws or wedges re-adjusted. To move a cylinder, if the connections be short and stiff, remove the bolts which tie it to the bed-plate, then measure from the plane of the cylinder to some fixed object such as a wall, post or column, cut a plank or scantling about an inch longer than the actual measurement from the cylinder to the wall, so that when placed against the cylinder, it may stand slightly oblique; then by driving on the end of the plank with a sledge or heavy hammer, the cylinder may easily be moved. The holes should then be reamed, and new bolts corresponding to the reamer substituted for the old ones. The cylinders, guides, and pillow-blocks of all engines should be double pinned to prevent them from getting out of line, and whenever it becomes necessary from wear to move them, the holes may be re-reamed, and new pins substituted.

THE FIRST SAW MILLS.

The old practice in making boards was to split up the logs with wedges, and, inconvenient as the practice was, it was no easy matter to persuade the world that the thing could be done in any better way. Saw mills were first used in Europe in the fifteenth century; but so lately as 1555, an English embassador, having seen a saw mill in France, thought it a novelty which deserved a particular description. It is amusing to note how the aversion to labor saving machinery has always agitated England. The first saw mill was established by a Dutchman, in 1663; but the public outcry against the new-fangled machine was so violent, that the proprietor was forced to decamp with more expedition than ever did Dutchman before. The evil was thus kept out of England for several years, or rather generations; but in 1768 an unlucky timber merchant, hoping that after so long a time the public would be less watchful of its own interests, made a rash attempt to construct another mill. The guardians of the public welfare, however, were on the alert, and a conscientious mob at once collected, and pulled the mill to pieces.

DECLIVITY OF RIVERS.

A very slight declivity suffices to give the running motion to water. Three inches per mile in a smooth, straight channel gives a velocity of about 3 miles an hour. The Ganges, which gathers the waters of the Himalaya mountains, the loftiest in the world, is, at 180 miles from its mouth, only 800 feet above the level of the sea, and to fall these 800 feet in the long course the water requires more than a month. The great river Magdalena, in South America, running for 1,000 miles between two ridges of the Andes, falls only 500 feet in all that distance; above the commencement of the 1,000 miles it is seen descending in rapids and cataracts from the mountains. The gigantic Rio de la Plata has so gentle a descent to the ocean that, in Paraguay, 1,500 miles from

its mouth, large ships are seen which have sailed against the current all the way by the force of the wind alone—that is to say, which, on the beautiful inclined plane of the stream, have been gradually lifted by the soft wind, and even against the current, to an elevation greater than that of our loftiest spires.

MILLERS AND THE LAW ON WATER COURSES.

Very curious and interesting disputes are constantly coming before the courts, relative to the rights of millers and manufacturers on the streams which afford them power. Any one who has taken pains to note the tenor of the decisions in these cases, will see that they conform to certain established principles of law, with which every mill-owner would do well to be conversant.

The word "riparian" (from the Latin *ripa*—meaning the bank of a river) is a term used in law to refer to the rights and privileges of persons who own lands lying upon or bounded by streams or rivers. It is fixed in law and confirmed by court decisions, that every riparian proprietor has an equal right to a free use of the water which passes his land. He has, however, no exclusive property in the water itself, but the simple use of it as it passes. He can not appropriate it to his exclusive use nor divert it permanently from its natural channel without the consent of the adjoining proprietors. If he does divert it on his own premises, he must return it to its ordinary course when it leaves his estate.

These are the broad principles upon which the general and state laws are based. Of course the minor details of water rights, etc., are subject to local state enactments, forms and restrictions, otherwise streams of running water could rarely be properly applied to agricultural or manufacturing purposes. In all instances it may be taken for granted that nothing but positive surrender of rights or contract to the contrary, can deprive the riparian proprietor of the use of the stream passing him until he has had use of it, if he wishes to employ it legitimately.

If the water is insufficient for the mill-owner's purposes, but can be made, by a reasonable detention, available for power, the courts have decided that he can so retain it until he has enough to use profitably. The mill-owners further down must do the best they can, being, of course, entitled to their share of the water when it gets to them in regular course. Again, as to protecting himself from damage by freshet or overflow, he can erect such protection as may be necessary in the way of embankments, etc., even though such protective measures may back the water upon adjoining land. The land-owner in the latter case has no legal cause for action.

Of course no mill-owner would be justified in the malicious detention or wastage of water, or in the unwarrantable release of water so as to destroy neighboring property. He has, however, the inalienable rights of proper use of the water and of protecting himself from its ravages, let others do what they will.

In this connection, though not directly in the line of the foregoing is an interesting decision rendered in the Supreme Court of New York. The defendant had on his land a spring surrounded by an embankment. The plaintiff had a well which was dependent upon the defendant's spring for supply. The defendant cut through the embankment, thereby lowering the water in the well of the plaintiff. The court held that the plaintiff had no cause for action, no matter what was the defendant's motive. The laws and courts throughout seem to decide that the elements air and water are the untrammeled property, for the time being, of those brought into natural contact with them.

PREVENTION OF INCRUSTATION OF STEAM BOILERS.

The following condensed hints will be found valuable: (1) Use as pure water as your locality affords. (2) Clean and scrape your boiler as often as you possibly can. (3) Blow off without excess. (4) In case of salt or brackish waters, never use steam of over 90 lbs. pressure to the square inch. (5) In case of sulphate of lime waters, never use steam of over 70 lbs. pressure. (6) In case of water holding carbonate of lime in solution, pass it through a feed-water heater made hot by exhaust steam or waste heat. (7) In case of muddy waters use large feed-water cisterns or reservoirs, on the bottom of which the suspended earthy matters will soon form a soft deposit, when the surface water can be drawn off for use. When using hard water, save the drippings of the exhaust-pipe, and the condensation of the safety-valve blow-off, and from the cylinder, and use the water thus obtained to fill the boiler after blowiug off. The result will be surprising in its effect in loosening scale.

The following remedies have been used with more or less success in various cases: (1) Potatoes 1-50 of weight of water, prevents adherence of scale. (2) Twelve parts salt, 2½ caustic soda, ⅛ extract of oak bark, ½ part of potash. (3) Pieces of oak wood, suspended in a boiler and renewed monthly, prevent deposit. (4) Two ounces of muriate of ammonia in a boiler twice a week, prevents incrustation and decomposes scale. (5) Coating of 3 parts black lead, 18 of tallow, applied hot to the inside of a boiler every few weeks, prevents scale. (6) Thirteen pounds of molasses fed occasionally into an 8-horse boiler prevented incrustation for six months. (7) Mahogany or oak sawdust in limited quantities. The tannic acid attacks the iron, and should be used with caution, (8) Slippery elm bark has been used with some success. (9) Carbonate of Soda. (10) Chloride of tin. (11) Spent tanner's bark. (12) Frequent blowing off.

HOW TO UTILIZE SAW-DUST.

This is a frequent query among our saw-mill men. The general practice of throwing saw-dust and saw-mill waste into streams has

become so serious a matter in Minnesota and Wisconsin, that the most stringent legislation is being proposed upon this subject. A bill has been introduced into congress, forbidding mill owners to deposit in any of the navigable waters of the United States any saw-dust, slabs, or wastage, and fixing as penalty a fine of from $500 to $5,000, and in default of payment, imprisonment for not more than six months. Provision is also made for the institution of civil suits in the name of the United States, against those who disobey this prohibition, and if violation of the statute be admitted or proved the damages in all cases to be $500, and such further sums as the court may adjudge. The Government has been expending considerable money in efforts to deepen some of these streams, with a view to benefitting navigation; but their efforts and expenditures are useless if, as fast as the channels are cleaned out, they are refilled with this artificial obstruction.

Saw-dust has been used to a limited extent in the manufacture of various articles for wood ornamentation, taking the place of carved work. It has also been employed in making imitation ebony keys, brush handles, knife handles, etc. For all of these purposes it is reduced to a plastic mass, mixed with glue or gypsum, and shaped by pressure in molds. Fire kindlers and blocks for fuel have been made with profit from the same material, and it has also been used as fuel under boilers. A patent has even been issued for the manufacture of railroad ties, fence posts, paving and building blocks, &c., from saw-dust. This artificial wood, it is claimed, can be made fire and water proof, and no insect will attack it. It will take polish and will stand higher pressure than ordinary wood. It also can be cut and sawed and allow nails to be driven into it. As the process of making it is very simple and cheap, it may be destined to bring a revolution in the saw-mill business; but in all these and the various other ways reported, but a very small proportion of the saw-dust product of this country could ever be utilized

The most valuable and practicable suggestion comes from a Louisiana planter, who says that for fertilizing purposes saw-dust has remarkable advantages. Spread from 6 to 12 inches thick over newly planted potatoes, it is said to have a marked and favorable effect on the yield. Another and perhaps preferable method is to prepare the soil by plowing and pulverizing, to open furrows 2 to 3 feet apart, to put in said furrows a 4 inch layer of saw-dust, on this lay the potatoes that are to be planted, covering them with another layer of saw-dust, and over this a layer of the soil.

Saw-dust, says the same authority, can be used with advantage about fruit trees. Mixed with the soil it enriches the latter, and placed on its surface it maintains moisture and prevents the growth of many troublesome weeds. In vegetable gardens it also does very well, especially around cabbage plants. Saw-dust will rot as soon as any other vegetable matter, according to the species from which it originates. Mixed with the soil it keeps the latter more mellow. An application of saw-dust, say of three cart loads to the acre, during four years, over

the poorest land, and plowing, and cultivating same each year, will render it the most fertile.

So long as manufactories are actually making chemical fertilizers, and our farmers are paying high prices for them, it would seem worth their while to investigate this newly suggested source of supply; especially when this supply comes in the shape of a substance which has hitherto been regarded as an actual nuisance to be sunken out of sight in rivers, and to be annihilated by burning in useless, ineffectual fires.

SPEED, POWER, CAPACITY AND DRESS OF MILLSTONES.

We herewith reproduce from the London *Miller*, a compact and suggestive table giving an estimate of the speed, power, capacity, dress, and draught of millstones of various diameters, as practiced in Great Britain for grinding wheat, where no exhaust or combined blast and exhaust are used. The table is compiled from the opinions of some of the most successful engineers and mill-wrights in the kingdom:

Diameter of millstone.		Revolutions per minute.	Horse Power.	Average capacity per hour of grinding in bushels through the journey.	Usual dress.	Draught from fore edge of furrows.
Ft.	In.					Inches.
2	6	200	2½	2½	7.3	2½
2	10	180	2¾	2¾	8.3	2½
3	0	170	3	3	9.3	2½
3	2	160	3¼	3¼	9.3	2¾
3	4	150	3½	3½	10.3	3
3	6	140	3¾	3¾	10.3	3
3	8	130	3⅞	3⅞	10.3	3
3	10	125	3⅞	Nearly 4	11.3	3
4	0	120	4	4	10.4	3
4	2	115	4⅛	4¼	10.4	3
4	4	110	4¼	4½	11.4	3¼
4	6	105	4½	5	12.4	3½
4	8	100	4¾	6	12.4	3¾
4	10	95	5	6½	12.4	4
5	0	90	6	7	12.4	4½

In commenting upon and in further explanation of this table, the above named journal says that with reference to the figures, there exists

some difference of opinion, and subjoins the ideas of a Scotch engineer and millwright of considerable experience and influence, who claims that there should be only *four* standard diameters of millstones, viz:

3 ft. 3 ft. 6 in. 4 ft. 4 ft. 6 in.

The speed should be 170 revolutions for the 3 ft., 155, 135, and 115 for the remainder respectively; and he estimates that all these sizes would each absorb six *indicated* horse power to grind four bushels of wheat per hour. Thus a 3 ft. millstone, running 170 revolutions per minute, would take as much power, and will grind as much per hour, as a 4 ft. 6 in. running at 115 revolutions per minute, the only difference being that the 3 ft. millstone would require to be more frequently dressed. The correspondent adds that he thinks it could be very much simplified by taking the 4 ft. stone, running at 135, as the standard, and is convinced, after 30 years' experience, that for grinding wheat (at any rate) this size and speed might be adopted universally, with superior results as a whole, than by using the various sizes and speeds given in the above. Regarding the speed, however, all mills should be constructed so that the speed of the millstones could be varied, *when working*, either by driving each pair by a separate engine or by conical drums, as the various kinds of wheat, or even the state of the weather requires that the miller should have it in his power to vary his speed as easily as he can alter the feed.

While the foregoing table, with the modifications suggested by the Scotch engineer, may be applicable in cases where good, economical engines, which work fully up to nominal horse power are used, it would fall far short in its application to many turbines manufactured at the present time. The latter are frequently tabled for much higher power than can be realized from them, and by no possible means can they be made to work beyond their normal or stated power, while an engine can readily and easily be made to do so by a small increase of pressure or piston speed. Again, water wheels which are capable of working nearly or quite to their nominal power are very often,—perhaps in a majority of cases,—so put into operation as to prevent them from doing even what they should, were they more favorably situated and attached to the work.

In a note upon the blast and exhaust the *Miller* says:

"It is stated by some parties favorable to the combined Blast and Exhaust that, by the adoption of that system, a saving of power is effected, and that eight bushels of wheat can be ground by *six*-horse power. The power, however, being unlimited, the quantity ground can be increased almost indefinitely, in the above proportion, according to the weight of the millstone, sixteen bushels per hour often being ground on this system. The application of the Exhaust, drawing the air through the eye of the running millstone, does not produce a greater current than that of atmospheric pressure, the millstones grind somewhat faster, and there is a corresponding amount of economic power, the millstones working more freely. Many advantages in this respect result from the adoption of the simple Exhaust, having for its

object the removal only of the stive from the millstone case."

The same journal also adds, with reference to reckoning the draught, that it has been the custom of millers usually to reckon the draught from the *back edge* of the furrow, while millstone makers calculate from the *fore edge*. The *latter*, it states, is now becoming a rule in the trade.

CHARACTERISTICS OF VARIOUS WOODS.

The following is a general statement of the commercial value and properties of the better known woods:

Elasticity.—Ash, hickory, hazel, lancewood, chestnut (small,) yew, snakewood.

Elasticity and toughness.—Oak, beech, elm, lignum-vitæ, walnut, hornbeam.

Even grain (for carving or engraving).—Pear, pine, box, lime tree.

Durability (in dry works).—Cedar, oak, poplar, yellow pine, chestnut.

Building (ship-building).—Cedar, pine, (deal), fir, larch, elm, oak, locust, teak. Wet construction (as piles, foundations, flumes, etc.)—. Elm, alder, beech, oak, plane tree, white cedar. House building.—Pine, oak, whitewood, chestnut, ash, spruce, sycamore.

Machinery and millwork (frames).—Ash, beech, pine, elm, oak. Rollers, etc.—Box, lignum-vitæ, mahogany. Teeth of wheels.—Crab tree, hornbeam, locust. Foundry patterns.—Alder, pine, mahogany.

Furniture (common).—Beech, birch, cedar, cherry, pine, whitewood. Best furniture.—Amboyna, black ebony, mahogany, cherry, maple, walnut, oak, rosewood, satinwood, sandalwood, chestnut, cedar, tulip wood, zebra wood, ebony.

Of these varieties, those that chiefly enter into commerce in this country, are oak, hickory, ash, elm, cedar, black walnut, maple, cherry, butternut, etc.

TO FIND THE SOLID CONTENTS OF TIMBER.

ROUND TIMBER.

When all the dimensions are in feet.

The length multiplied by square of ¼ of the mean girth gives the number of cubic feet.

When length in feet, girth in inches.

Multiply as above, and divide by 144.

When all dimensions are in inches.

Multiply as above, and divide by 1728.

SQUARE TIMBER.

When all dimensions are in feet.

The length multiplied by the breadth multiplied by the depth gives the number of cubic feet.

When either dimensions are in inches.

Multiply as above and divide by 12.

When any two of the dimensions are in inches.

Multiply as above, and divide by 144.

Or use the following table as shown at foot of same.

TABLE ONE-FOURTH GIRTHS.

¼ Girth in inches.	Area in Feet.	¼ Girth in inches.	Area in Feet.	¼ Girth in inches.	Area in Feet.
6	.250	12¼	1.04	19	2.50
¼	.272	½	1.08	½	2.64
½	.294	¾	1.12	20	2.77
¾	.317	13	1.17	½	2.91
7	.340	¼	1.20	21	3.06
¼	.364	½	1.26	½	3.20
½	.390	¾	1.31	22	3.36
¾	.417	14	1.36	½	3.51
8	.444	¼	1.41	23	3.67
¼	.472	½	1.46	½	3.83
½	.501	¾	1.51	24	4.00
¾	.531	15	1.56	½	4.16
9	.562	¼	1.61	25	4.34
¼	.594	½	1.66	½	4.51
½	.626	¾	1.72	26	4.69
¾	.659	16	1.77	½	4.87
10	.694	¼	1.83	27	5.06
¼	.730	½	1.89	½	5.25
½	.766	¾	1.94	28	5.44
¾	.803	17	2.00	½	5.64
11	.840	¼	2.06	29	5.84
¼	.878	½	2.12	½	6.04
½	.918	¾	2.18	30	6.25
¾	.959	18	2.25		
12	1.000	½	2.37		

The area corresponding to the ¼ girth in inches multiplied by the length in feet gives solidity in feet and decimal parts for either square or round timber.

For Round Timber take the *mean* girth. For Square Timber take the side, which in practice corresponds with ¼ of the girth of Round Timber.

COMPOSITION FOR COVERING BOILERS.

A composition for covering boilers, steam pipes, etc., cheap and said to be effective is made as follows: The surfaces are covered with sawdust mixed with flour paste. If the paste is not very liquid, the

mixture being used in the form of moderately stiff dough, and the surfaces of the boilers or pipes have been well cleaned from grease, the adhesion is perfect and the material is free from cracks. Five layers of this composition are recommended, each about one-fifth of an inch thick. It is said that 1 inch of this composition will give better results than double that amount of the materials usually employed, The paste is composed of rough flour without the addition of starch. The mixture can be applied without a trowel, and, if there is much exposure, two or three coatings of tar will render the composition impervious to water. Copper tubes should first be treated to a hot liquid solution of clay, so as to increase the adhesion of the sawdust.

WEIGHTS AND MEASURES.

AVOIRDUPOIS WEIGHT.

[THE GRAIN IS THE SAME IN TROY, APOTHECARIES AND AVOIRDUPOIS WEIGHTS.]

The standard avoirdupois pound is the weight of 27.7015 cubic inches of distilled water weighed in the air, at 35.85 degrees Fahr., barometer at 30 inches:

27.343 grains equals 1 drachm.

drachms.		ozs.		lbs.		qrs.		cwts.		ton.		French grammes.
1	equals	.0625	eq.	.0039	eq.	.000139	eq.	.000035	eq.	.00000174	eq.	1.771846
16	"	1	"	.0625	"	.00223	"	.000558	"	.000028	"	28.34954
256	"	16	"	1	"	.0357	"	.00893	"	.000447	"	453.59
7168	"	448	"	28	"	1	"	.25	"	.0125	"	12700
28672	"	1792	"	112	"	4	"	1	"	.05	"	50802
573440	"	35840	"	2240	"	80	"	20	"	1	"	1016040

A stone equals 14 pounds. A quintal equals 100 pounds.

TROY WEIGHT.

[FOR GOLD, SILVER AND PRECIOUS METALS.]

grains.		dwts.		ozs.		lbs.		French grammes.
1	equals	.04167	equals	.00208	equals	.0001736	equals	.0648
24	"	1	"	.05	"	.004167	"	1.555
480	"	20	"	1	"	.0833	"	31.1035
5760	"	240	"	12	"	1.	"	373.242

175 lbs. Troy equals 144 Avoirdupois.
Lbs. Avoirdupois X .82286 equals lbs. Troy.
Lbs. Troy X 1.2153 " " Avoirdupois.

The jewelers' carat is equal, in the United States, to 3.2 grains; in London, to 3.17 grains; in Paris, to 3.18.

Pure gold is worth	$20.67 per oz.	Troy, or		$18.84 per oz.	Avoirdupois.	
" silver "	1.36	"	"	1.24	"	"
Standard gold "	18.60	"	"	16.96	"	"
" silver "	1.225	"	"	1.117	"	"

APOTHECARIES' WEIGHT.

[UNITED STATES AND BRITISH.]

20 grains	1 scruple.			
3 scruples	1 drachm equals 60 grs.			
8 drachms	1 ounce "	24 scruples equals 480 grs.		
12 ounces	1 pound "	96 drachms "	288 scruples equals 5760 grs.	

In Troy and Apothecaries' weights the grain, ounce, and pound are the same.

FRENCH WEIGHTS.

[EQUIVALENT IN AVOIRDUPOIS.]

	Grains.	Ounces.	Pounds.	Tons 2240 lbs.
Milligramme	.015433	....	....	....
Centigramme	.154331	.000352	.000022	....
Decigramme	1.54331	.003527	.000220	....
Gramme	15.4331	.035275	.002204	....
Decagramme	154.331	.352758	.022047	....
Hectogramme	1543.31	3.52758	.220473	.000098
Kilogramme	15433.1	35.2758	2.20473	.000984
Myriogramme	....	352.758	22.0473	.009842
Quintal	....	3527.58	220.473	.098425
Millier or Tonne	....	35275.8	2204.73	.984257

CUBIC MEASURE.

INCHES.		FEET.		YARD.		CUB. METRES.
1	equals	.0005788	equal	.000002144	equal	.000016386
1728	"	1	"	.03704	"	.028315
46656	"	27	"	1	"	.764513

A cord of wood equals 128 cubic feet, being 4 feet high, 4 feet wide, and 8 feet long.

42 cubic feet equals a ton of shipping.

A cubic foot is equal to

1728 cubic inches.
.037037 cubic yard.
.803564 U. S. struck bush. of 2150.42 cubic inches.
3.21426 U. S. pecks.
7.48052 " liq. galls. of 231 cubic in.
6.42851 " dry galls.
29.92208 U. S. liquid quarts.
25.71405 " dry "
59.84416 " liquid pints.
51.42809 " dry "
239.37662 " gills.
.26667 flour bbl. of 3 struck bush.
.23748 U. S. liq. bbl. of 31½ gallons.

LIQUID MEASURE.

Gills.								
4 equal	1 Pint.							
8 "	2 equal	1 Quart.						
32 "	8 "	4 equal	1 Gallon.					
1314 "	336 "	168 "	42 equal	1 Tierce.				
2016 "	504 "	252 "	63 "	1½ equal	1 Hogshead.			
2488 "	672 "	336 "	84 "	2 "	1⅓ equal	1 Puncheon.		
4032 "	1008 "	504 "	126 "	3 "	2 "	1½ equal	1 Pipe.	
8064 "	2016 "	1008 "	252	6 "	4 "	3 "	2 equal	1 Tun.

Cylinders of the following sizes are closely approximating measures:

	Height in Inches.	Diameter in Inches.		Height in Inches.	Diameter in Inches.
Gill	3	1¾	Quart	6	3½
½ Pint	3⅝	2¼	Gallon	6	7
Pint	3	3½	10 Gallons	15	14

A cubic foot contains 7½ gallons.

DRY MEASURE.

The Standard Bushel contains 2150.42 cubic inches, or 77.627013 pounds avoirdupois of pure water at maximum density. Its legal dimensions are 18½ inches diameter inside, 19½ inches outside, and 8 inches deep, and when heaped, the cone must be 6 inches high, making a heaped bushel equal to 4¼ struck ones.

Pints.		Quarts.		Gallons.		Pecks.		Bushels.		Cub. Inches.
2	equal	1	equal	.250	equal	.125	equal	.0315	equal	67.2
8	"	4	"	1	"	.5	"	.125	"	268.8
16	"	8	"	2	"	1	"	.25	"	537.6
64	"	32	"	8	"	4	"	1		2150.42

LONG MEASURE.

Inches.	Feet.	Yards.	Fath.	Poles.	Furlong.	Mile.	French Metres.
1	.083	.02778	.0139	.005	.000126	.0000158	.0254
12	1	.333	.1667	.0606	.00151	.0001894	.3048
36	3	1	5	.182	.00454	.000568	.9141
72	6	2	1	.364	.0091	.001136	1.8287
198	16½	5½	2¾	1	.025	.003125	5.0291
7920	660	220	110	40	1	.125	201.16
63360	5280	1760	880	320	8	1	1609.315

A palm equals 3 inches. A hand " 4 "

A span equals 9 inches. A cable's length equals 120 fathoms.

SQUARE MEASURE.

Inches.	Feet.	Yards.	Perches.	Roods.	Acre.	Square Metres.
1	.00694	.000772	.0000255	.00000064	.000000159	.000645
144	1	.111	00367	.0000918	.000023	.0929
1296	9	1	.0331	.000826	.000206	.8361
39204	272¼	30¼	1	.025	.00625	25.292
1568160	10890	1210	40	1	.25	1011.7
6272640	43560	4840	160	4	1	4046.7

100 square feet equal 1 square.
1 chain wide " 8 acres per mile.
10 square chains " 1 acre.
1 hectare " 2.471143 acres.
1 square mile " 27878400 sq. feet.
" 3097600 sq. yds.
" 640 acres.
Acres x .0015625 " square miles.
Sq. yds. x .000000323 " square miles.
A section of land is 1 mile square, and contains 640 acres.
A square acre is 208.71 feet at each side.
" ½ " 147.58 " "
" ¼ " 104.355 " "
A circular " 235.504 feet in diameter.
" ½ " 166.527 " "
" ¼ " 117.752 " "

SURVEYING MEASURE.

(LINEAR.)

Inches.	Links.	Feet.	Yards.	Chains.	Miles.	French Metres.
1	.126	.0833	.0278	.00126	.0000158	.0254
7.92	1	.66	.22	.01	.000125	.2012
12	1.515	1	.333	.01515	.000189	.3048
36	4.545	3	1	.04505	.000568	.9144
792	100	66	22	1	.0125	20.116
63360	8500	5280	1760	80	1	1600.315

1 knot or geographical mile equals 6082.66 feet, or 1854 metres, or 1.152 statute mile.

1 Admiralty knot equals 1.1515 statute miles, or 6080 feet.

FRENCH LONG MEASURE.

	Inches.	Feet.	Yards.	Miles.
Millimetre	.03936	.00328	.001093	....
Centimetre	.39368	.03280	.010935	....
Decimetre	3.9368	.32807	.109357	....
Metre	39.368	3.2807	1.09357	.0006213
Decametre	393.68	32.807	10.9357	.0062134
Hectometre	3936.8	328.07	109.357	.0621347
Kilometre	39368.	3280.7	1093.57	.6213476
Myriametre	....	32807.	10935.7	6.213476

FRENCH CUBIC OR SOLID MEASURE.

	Gill.	Pint.	Quart.	Gallon.	Peck.	Bushel.	Cubic Inches.	Cubic Feet.
Centilitre,								
Dry	....	.0181	....	....	....	....	.61016	....
Liquid	.0845	.0211	....	....	....	....		
Decilitre,								
Dry	....	.1816	.0908	....	.0113	....	6.1016	....
Liquid	.8452	.2113	.1056	.0264	....	....		
Litre,								
Dry	....	1.816	.908	....	.1135	....	61.016	.0353
Liquid	8.452	2.113	1.056	.2641	....	....		
Decalitre,								
Dry	....	....	9.08	....	....	.2837	610.165	.3531
Liquid	84.52	21.13	10.56	2.641	1.135	....		
Hectolitre,								
Dry	....	....	90.8	....	11.35	2.837	6101.6	3.531
Liquid	....	211.3	105.6	26.41	....	....		
Kilolitre or Cub. Metre,								
Dry	....	....	....	....	113.5	28.37	61016.	35.31
Liquid	....	....	1056.5	264.1	....	....		
Myriolitre,								
Dry	....	....	....	....	1135.	283.72	....	353.1
Liquid	....	....	10565.	2641.4	....	....		

FRENCH SQUARE MEASURE.

	Inches.	Feet.	Yards.	Acres.	Miles.
Sq. Millimetre...........	.00154	.0000107	.000001	....	....
" Centimetre............	.15498	.0010763	.000119	....	....
" Decimetre.............	15.498	.1076305	.011958	....	....
" Metre or Centiare..	1549.8	10.76305	1.19589	.000247	....
" Decametre or Are.	154980	1076.305	119.589	.024709	....
" Hectare................	....	107630.5	11958.9	2.47086	....
" Kilometre............	....	10763050	1195890	247.086	.38607
" Myriametre..........	....	....	....	2470.860	38.607

PROPERTIES OF THE CIRCLE.

Diameter multiplied by 3.14159, equals circumference.
Diameter multiplied by .8862, equals side of an equal square.
Diameter multiplied by .7071, equals side of an inscribed square.
Diameter^2 multiplied by .7854, equals area of circle.
Radius multiplied by 6.28318, equals circumference.
Circumference divided by 3.14159, equals diameter.

The circle contains a greater area than any plane figure bounded by an equal perimeter or outline.

The areas of circles are to each other as the squares of their diameters.

Any circle whose diameter is double that of another contains four times the area of the other.

Area of a circle is equal to the area of a triangle whose base equals the circumference, and perpendicular equals the radius.

CEMENT FOR LEATHER BELTING.

Take of common glue and American isinglass, equal parts; place them in a boiler and add water sufficient to cover the whole. Let it soak 10 hours, then bring it to a boiling heat, and add pure tannin until the whole becomes ropy or appears like the white of eggs. Apply it warm. Buff the grain off the leather where it is to be cemented; rub the joint surfaces solidly together, let it dry a few hours, and it is ready for practical use; and, if properly put together, it will not need riveting, as the cement is nearly of the same nature as the leather itself.

CEMENT FOR STOPPING JOINTS.

A cement which grows hard by exposure and resists heat, cold and water, is made by mixing white lead in oil with enough white sand to make a stiff paste.

MEASUREMENT OF ROUND TIMBER.

TABLE GIVING CUBICAL CONTENTS.—[BY E. N. COLWELL.]

Diameter in inches, length in feet, contents in cubic feet.

Length in Feet.	Mean Diameter in Inches.														
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
8	4	5	6	7	8	10	11	12	14	16	17	19	21	23	25
9	5	6	7	8	9	11	12	14	16	18	20	22	24	26	28
10	5	7	8	9	10	12	14	16	18	20	22	24	26	29	31
11	6	7	8	10	12	13	15	17	19	22	24	26	29	32	35
12	6	8	9	11	13	15	17	19	21	24	26	29	32	34	38
13	7	9	10	12	14	16	18	20	23	26	28	31	34	37	41
14	7	9	11	13	15	17	19	22	25	28	31	34	37	40	44
15	8	10	12	14	16	18	21	23	26	30	33	36	40	43	47
16	9	11	12	14	17	20	22	25	28	32	35	38	42	46	50
17	9	11	13	16	18	21	24	27	30	33	37	41	45	49	53
18	10	12	14	16	19	22	25	28	32	35	39	43	48	52	57
19	10	13	15	17	21	23	27	30	33	37	41	45	50	55	60
20	11	13	16	18	21	25	28	31	35	39	44	48	53	58	63
21	11	14	16	19	22	26	29	33	37	41	46	50	55	61	66
22	12	15	17	20	23	27	31	35	39	43	48	53	58	64	69
23	12	16	18	21	24	28	32	36	41	45	50	55	61	66	72
24	13	16	19	22	26	30	34	38	42	47	52	58	63	69	75
25	14	17	20	23	27	31	35	39	44	49	54	60	66	72	79
26	14	17	20	24	28	32	36	41	46	51	57	63	69	75	82
27	15	18	21	25	29	33	38	42	48	53	59	65	71	78	85
28	15	18	22	26	30	35	39	44	49	55	61	67	74	81	88
29	16	19	23	27	31	36	41	45	51	57	63	70	77	84	91
30	16	20	24	28	32	37	42	47	53	59	65	72	79	86	94
31	17	20	24	29	33	38	43	48	55	61	68	75	82	89	98
32	17	21	25	29	34	40	45	50	57	63	70	77	85	92	100
33	18	22	26	30	35	41	46	52	58	65	72	79	87	95	104
34	19	22	27	31	36	42	48	53	60	67	74	82	90	98	107
35	19	23	28	32	37	43	49	55	62	69	76	84	93	101	110
36	20	24	28	33	39	44	50	57	64	71	79	86	95	104	113

MEASUREMENT OF ROUND TIMBER.—*Continued.*

Diameter in inches, length in feet, contents in cubic feet.

Length in Feet.	Mean Diameter in Inches.													
	25	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**
8	27	29	32	34	37	39	42	45	48	50	53	56	60	62
9	31	33	36	38	41	44	47	50	53	57	60	64	67	70
10	34	37	40	43	46	49	52	56	59	63	67	71	75	79
11	37	41	43	47	50	53	57	61	65	69	73	77	82	86
12	41	44	47	51	55	58	62	67	71	76	80	85	90	94
13	44	48	51	56	60	63	68	72	77	82	87	92	97	102
14	48	52	55	60	64	68	73	78	83	88	94	99	105	110
15	51	55	59	64	69	73	78	84	89	95	100	106	112	118
16	55	59	63	68	73	78	83	89	95	101	107	113	119	126
17	58	63	68	73	78	83	89	95	101	107	114	121	127	135
18	61	66	72	77	82	88	94	100	106	114	120	128	134	142
19	65	70	75	81	87	93	99	106	112	120	127	135	142	151
20	68	74	79	85	91	98	105	112	118	126	134	142	149	159
21	71	77	83	90	96	103	111	117	124	132	140	149	157	166
22	75	81	87	94	101	109	116	123	130	139	147	156	164	174
23	78	85	91	98	105	113	121	128	136	145	154	163	172	183
24	82	88	95	102	111	118	127	134	143	151	160	170	179	191
25	85	92	99	107	116	123	131	139	149	158	167	178	187	198
26	89	96	103	111	120	128	137	145	154	164	174	185	194	206
27	92	99	107	115	125	133	142	151	160	170	180	192	202	214
28	95	103	111	120	129	136	147	156	166	177	187	198	209	222
29	99	107	115	124	134	143	153	162	172	183	194	206	217	228
30	102	110	119	128	138	148	158	168	177	189	200	213	224	236
31	106	114	123	132	143	152	163	173	182	195	207	220	232	244
32	109	118	127	137	148	157	169	178	188	202	214	227	239	253
33	112	121	130	141	152	162	174	184	194	208	220	234	247	261
34	116	125	135	145	157	167	179	190	200	214	227	241	254	268
35	119	129	139	149	161	172	182	196	205	220	234	248	261	276
36	123	133	143	154	169	177	190	201	212	227	240	255	269	284

ON COUNTERBALANCING RECIPROCATING PARTS.

[BY PROF. S. W. ROBINSON, IN LEFFEL NEWS.]

A weight is often attached to a crank-wheel opposite the crank-pin, or upon an over-reaching arm of a crank for the purpose of quieting the vibrations of a jig-saw, or of the piston, cross-head, etc., of an engine. Many times the experimenter, after trying different weights, has wondered why his best attainable result was so far from being satisfactory.

The reason why the result was so disappointing is, that it is simply not possible to perfectly balance a reciprocating piece by a rotating piece. This is owing to the fact that the reciprocating piece gives a jerk at each end of its stroke, and in the line of the stroke, while the rotating piece throws out all around, with a constant centrifugal force. The counter-weight may be such as to produce nearly a perfect balance in one direction, say in line of the reciprocation; or it may have another weight such as to balance the mechanism in a direction at right angles to reciprocation. Advantage should be taken of this fact, and the mechanism so counter-weighted as to adapt it for its particular location when set up.

For instance, if a jig-saw is to stand on a tall brick pier, it should be counterbalanced so as to give no horizontal shake. Then the pier and the earth will easily resist the vertical jerks, while horizontally there will be none to shake the pier to pieces. Again if the jig-saw is to be set up in the middle of a broad floor, in a second story of a building, where it is not convenient to place a prop under it, and where the floor is well secured all around to the brick walls of the building, the horizontal thrusts have but little effect in vibrating the brick walls, or even wooden walls, while the vertical ones may shake the floor badly. In the first instance a light weight is needed, and in the last, a heavier one. Builders of machinery in which large reciprocating parts predominate, should send with the machines a weight for each condition of counter-balance.

High speed engines should be counter-balanced so as to give no horizontal jerks. A crank for a horizontal engine should be differently counter-balanced from a vertical one.

If two equal reciprocating parts play in lines at right angles to each other, receiving motion from the same crank-pin, the crank can be so counter-weighted as to very nearly exactly balance the parts. The counter-weight in that case should be as heavy as each reciprocating part, plus about half the weight of one pitman; provided the center of gravity of the weight be at the same distance from the axis of the crank-shaft as the crank-pin is. But if this distance be half that of the crank-pin, the weight should be twice as great, etc.

Now, if one of these reciprocating parts be removed, say that playing in a vertical line, then the mechanism will jerk badly vertically, but will remain in balance horizontally. To make it balance vertically it

will be necessary to remove all the weight but that part which stands for "about half the weight of one pitman."

To make a compromise balance, that is, to divide the shaking equally between the two directions, when there is only one reciprocating piece as just supposed above, it will be necessary to restore half the weight just supposed above to be removed.

These statements are based on three principles, viz: 1st. The centrifugal force, for a given number of revolutions, per second, is proportional to the radius. 2d. The centrifugal force of a revolving mass of any form, is the same as though that whole mass were concentrated at its center of gravity. 3d. The outward thrust of a reciprocating piece when changing its motion at the end of its stroke, is the same as the centrifugal force of that piece would be if it were taken off of the pitman, and attached to the crank-pin directly, with its center of gravity at the center of the pin.

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STEAM ENGINE GOVERNORS.

[BY STEPHEN ROPER, IN LEFFEL NEWS.]

The subject of regulating the speed of steam engines, and more especially those which from circumstances and the nature of the work to be performed are liable to constant change, has of late years received no little attention from engineers and practical inventors, and as a result various kinds of governors have been introduced. It would be safe to say that this device has absorbed more thought, and received more attention on the part of mechanics than any other adjunct of the steam engine. In the ordinary governor the principal part of the apparatus consists of a pair of balls revolving round a vertical axis or spindle driven by a train of mechanism, generally mitre gears, which causes their angular velocity of revolution to bear a fixed ratio to the velocity of the prime mover. The rods of the pendulums place themselves at an angle with the vertical axis, so that the common height of the pendulums is that corresponding to the number of turns in a second. The regulator must be so adjusted as to be in the proper position for supplying the proper amount of power when the pendulum rods are at the angle of inclination corresponding to the proper speed of the machine. When the speed deviates above or below that amount, the outward or inward motion of the pendulum-rods acts on the spindle, so as to open the valve when the speed is too low and close it when it is too high.

In the attainment of this object the principle of centrifugal force as embodied in the old fly ball governor of Watt has been more resorted to than any other, but aside from this, the governor has been so improved, altered, and reconstructed, since his time, as to be almost unrecognizable, but still the old principle is there and also the three prominent defects which so materially interfere with its efficiency. The

first of these is friction which arises from the joints, and is caused by swinging the balls or weights by the short end of the arm or lever to which they are attached. The second defect is due to the fact that the balls, as they assume different positions in keeping with the speed with which they revolve, are obliged to rise and fall. This is necessary in order that the resistance which the weights offer to centrifugal force should constantly increase; if it did not so increase, the weights, when once started from their position of rest, would instantly go to the extreme limit of motion. The rising of the balls shortens the distance which they are allowed to move for a given variation by springing the centers of ball and arm on which they swing into a straight line, so that a variation which moves the balls a given distance upward, if it occurs again, will not move them nearly so far in the same direction. Again the same force that would support the balls in any plane would not raise them to that plane from a lower one. So between friction which destroys the delicate power that the balls assume under a slight change and the necessity for a large change to overcome their inertia, it is almost impossible to attain a degree of regulation which would be equal to all requirements.

Governors when attached to throttle valves, work under circumstances that necessitate the use of openings for the passage of the steam that are too small in area, so much so that the useful effects of the steam are considerably diminished, on which depends the ill repute of throttling engines as compared with those which regulate by governor controlled valve motions or variable cut off. If the valve of a governor has too large openings, it will, owing to the unsteady action of the governor, admit too large a quantity of steam, and cause a jumping of the engine; then, in trying to shut off this extra amount, it shuts it all off; in fact the governor can not fix it exactly right, being incapable of delicate changes. This difficulty is best met by making the openings in the valve of peculiar shape so that they will open and close in a ratio different from that of the governor. With a governor that would run perfectly up to theory, and be steady and capable of taking a position in keeping with the speed, and not leaving it without a change in speed, a very large area might be used, and the useful effects of the steam would not be impaired, neither would there exist a necessity for large changes in speed to get the required opening and closing of the valve. The extra amount of steam required to drive a heavy addition of load on an engine is surprisingly small, provided that the engine can get the steam at the very instant the load is applied, and before the momentum of the machinery becomes much reduced; but let the engine once get below speed the circumstances will be very different, as even without any load the engines would take some time to come to speed.

The third defect in governors on throttling engines is that the spindle or valve-stem has of necessity to pass through steamtight packing or stuffing boxes, which have to be screwed up to prevent leakage, without any guide save the judgment of the engineer, which increases the friction, and interferes with the free action of the governor. There is

also the friction on the governor valve necessary to overcome the power required to move the valve-stem through all its bearings, stuffing boxes, guides, etc., under the pressure of steam. Were it possible to construct a governor for throttling engines which would approach in practice what theory would demonstrate, the fly ball or centrifugal governor would be a perfect regulator, but this appears according to mechanical laws to be impossible. By the use of isochronous governors which would not admit of any variation of speed, but would be in equilibrium at any speed, whether the balls were up or down, or in any other position, the defects of the common governor were supposed to be obviated, but it was found by experience that power and stability were necessary, and isochronism in its strict sense unattainable.

The economy of a good governor has rarely been appreciated by owners of steam engines and steam users. Experience has shown the speed best adapted for each and every process in the manufacturing and mechanical arts, and the governor that fails to meet all the varied requirements of each process is of no value in an economical point of view. Every stroke which an engine makes below its regular speed increases the cost of production, and every stroke above it is a waste of steam and consequently of fuel. If an engine is geared to run at 80 revolutions per minute, when a heavy piece of machinery is thrown off, the governor admits of an increase of speed of from 10 to 15 revolutions per minute. This incurs a waste of power, and consequently a waste of from 12 to 20 per cent. of fuel. On the other hand when a heavy piece of machinery is thrown on, the governor allows the engine to lag behind its regular speed by from 10 to 15 strokes per minute; it increases the cost of production. If a governor is unreliable it is worthless; if reliable its cost is merely a nominal consideration. There are many processes, such as milling, weaving delicate fabrics, printing from small type, or the very accurate turning of fine material, where a good governor is of immense value. Unfortunately for the progress of the mechanical arts no governor yet invented, has met all the necessary requirements, or the varied circumstances under which they are employed.

PROPORTIONS OF JOURNALS AND BEARINGS.

As the proper proportion of a journal has much to do with the safe and smooth operation of shafting, it will be well to consider what experience has taught on this subject. The element that will determine the proportions of a journal is the extent of pressure to which two surfaces of metal can be brought together without causing an abrasion of either, so that when the surface of a journal is so related to the pressure it sustains as to preserve a free and easy action between the surface of the journal and the boxing, and thus avoid undue wear of the parts, we may say that the journal is properly proportioned.

From various experiments it has been found that at a pressure of 180 pounds per square inch the limit has been reached where a journal will

operate without great wear or undue heating. A pressure of 240 pounds per square inch can be borne by the toes of vertical shafts, but it is only when provided with a base of the finest quality of metal upon which it turns, as well as the use of the best lubricant and the careful exclusion of all dust and fine gritty matter. Even under these circumstances it is difficult to avoid the heating of the toe to some extent. A general rule deduced from extended experience would give for cast iron shafts a length of journal one and one-half the diameter of the shaft, and for wrought iron shafts one and three quarters the diameter. This rule, it must be understood, applies only on the condition that a proper bearing surface is provided in the boxing.

Wooden boxes with a lining of sheet brass or copper have been frequently used, which almost always give serious trouble by heating, where they are required to sustain other than a very moderate pressure. The difficulty is obvious. The heat generated between the surfaces of the metal is prevented from passing off by reason of the non-conducting nature of the wood. The temperature is thus gradually raised by small and insensible increments of heat until it reaches a point where it expels the lubricating substance from between the surfaces, and a speedy destruction of the box ensues. A wooden box without this lining will be found in practice much preferable, as by reason of its porosity it will absorb a large amount of lubricating substance, which is given off at the slightest increase of heat, thus at once arresting a higher development of heat in the journal. It would therefore seem essential that a box should contain a reasonably large amount of metal, so that the heat produced by the friction of a journal may be rapidly diffused through its mass and carried away by radiation. The box, therefore, should never contain a less amount of metal than is contained in the journal it is designed to support. Even a larger amount may be considered essential to a proper proportion.

MEASUREMENT OF WATER IN PIPES.

A pipe 1 inch in diameter and 1 yard long will contain 28.26 cubic inches of water, or about one pound in weight. The capacity of a pipe increases in the ratio of the square of its diameter—that is to say, a pipe 2 inches in diameter contains four times as much, and one 3 inches in diameter nine times as much, as a pipe 1 inch in diameter. The practical rule, therefore, for finding the quantity of water in a pipe of any given diameter, is as follows, and is sufficiently exact for all ordinary requirements in mill work:

Square the diameter of the pipe in inches, and the product is the number of pounds weight of water in one yard of the pipe. As a gallon of water weighs about 10 pounds, divide the number of pounds by 10 (which is done by shifting the decimal point one place to the left) and the result is the number of gallons of water in one yard of the pipe.

For example, a pipe 8 inches in diameter will contain 64 pounds, or 6.4 gallons of water, for every yard of its length. For the total capacity of the pipe, it is only necessary, of course, to multiply the contents of one yard by the whole number of yards of the pipe's length.

A cubic foot of water weighs 62½ pounds, and contains 6¼ gallons. These figures have slight but unimportant variations.

HOW TO PRESERVE VARNISH BRUSHES.

For the preservation of brushes used in applying finishing varnish, an excellent method is to suspend them by the handles in a covered can, the points being kept well apart from each other and reaching say within half an inch of the bottom. The can having been filled with slow-drying varnish up to a line about one-sixteenth of an inch above the bristles or hair, should be kept in a box expressly fitted for the purpose, or if this is not convenient a close cupboard will answer.

The top of the can should have a wire soldered along the edge of the tin turned over, in order to prevent the injury which results from wiping a brush on a sharp edge of tin. This practice has the effect of gradually splitting the bristles and causing them to turn backward—treatment which no brush will long endure and remain serviceable. Turpentine should not be used in cleaning finishing brushes where it can be avoided. They may be prepared for use when taken from the can by working them out in varnish, and when replaced the handles and binding should be cleansed, for which purpose turpentine is suitable. No amount of skill on the part of the workman will enable him to execute a job neatly unless his brushes are kept in good condition—a principle which applies with equal force in all other branches of industry.

MEASUREMENT OF CIRCLES.

DIAMETERS, CIRCUMFERENCES AND AREAS.

On the ensuing six pages will be found an exceedingly convenient table for determining the circumference or area, or both, of any circle of which the diameter is given, the tables being calculated for diameters of 1-32 to 100 inclusive. If the diameter is in inches, the circum ference will be in inches and the area in square inches. If the diameter is in feet, the circumference will be feet and the area square feet—the figures being the same in either case.

The table gives the diameter in the first column, circumference in the second, and area in the third. It adds ⅛ of an inch (or of a foot, yard, rod, or any other unit of measurement,) to the diameter at each step; but in order not to crowd the column of diameters with figures, the places for ⅛, ⅜, ⅝ and ⅞ are left blank, though the proper circumferences and areas are given:

Dia.	Circ.	Area.	Dia.	Circ.	Area.	Dia.	Circ.	Area.
1–32	.0981	.00076	5	15.70	19.635	11	34.55	95.033
1–16	.1963	.00306		16.10	20.629		34.95	97.205
1/8	.3926	.01227	1/4	16.49	21.647	1/4	35.34	99.402
3–16	.5890	.02761		16.88	22.690		35.73	101.62
1/4	.7854	.04908	1/2	17.27	23.758	1/2	36.12	103.86
5–16	.9817	.07669		17.67	24.850		36.52	106.13
3/8	1.178	.1104	3/4	18.06	25.967	3/4	36.91	108.43
7–16	1.374	.1503		18.45	27.108		37.30	110.75
1/2	1.570	.1963	6	18.84	28.274	12	37.69	113.09
9–16	1.767	.2485		19.24	29.464		38.09	115.46
5/8	1.963	.3067	1/4	19.63	30.679	1/4	38.48	117.85
11–16	2.159	.3712		20.02	31.919		38.87	120.27
3/4	2.356	.4417	1/2	20.42	33.183	1/2	39.27	122.71
13–16	2.552	.5184		20.81	34.471		39.66	125.18
7/8	2.748	.6013	3/4	21.20	35.784	3/4	40.05	127.67
15–16	2.945	.6902		21.57	37.122		40.44	130,19
1	3.141	.7854	7	21.99	38.484	13	40.84	132.73
	3.534	.9940		22.38	39.871		41.23	135.29
1/4	3.927	1.227	1/4	22.77	41.282	1/4	41.62	137.88
	4.319	1.484		23.16	42.718		42.01	140.50
1/2	4.712	1.767	1/2	23.56	44.178	1/2	42.41	143.13
	5.105	2.073		23.95	45.663		42.80	145.80
3/4	5.497	2.405	3/4	24.34	47.173	3/4	43.19	148.48
	5.890	2.761		24.74	48.707		43.58	151.20
2	6.283	3.141	8	25.13	50.265	14	43.98	153.93
	6.675	3.546		25.52	51.848		44.37	156.69
1/4	7.068	3.976	1/4	25.91	53.456	1/4	44.76	159.48
	7.461	4.430		26.31	55.088		45.16	162.29
1/2	7.854	4.908	1/2	26.70	56.745	1/2	45.55	165.13
	8.246	5.411		27.09	58.426		45.94	167.98
3/4	8.639	5.939	3/4	27.48	60.132	3/4	46.33	170.87
	9.032	6.491		27.88	61.862		46.73	173.78
3	9.424	7.068	9	28.27	63.617	15	47.12	176.71
	9.817	7.669		28.66	65.396		47.51	179.67
1/4	10.21	8.295	1/4	29.05	67.200	1/4	47.90	182.65
	10.60	8.946		29.45	69.029		48.30	185.66
1/2	10.99	9.621	1/2	29.84	70.882	1/2	48.69	188.69
	11.38	10.320		30.23	72.759		49.08	191.74
3/4	11.78	11.044	3/4	30.63	74.662	3/4	49.48	194.82
	12.17	11.793		31.02	76.588		49.87	197.93
4	12.56	12.566	10	31.41	78.539	16	50.26	201.06
	12.95	13.364		31.80	80.515		50.65	204.21
1/4	13.35	14.186	1/4	32.20	82.516	1/4	51.05	207.39
	13.74	15.033		32.59	84.540		51.44	210.59
1/2	14.13	15.904	1/2	32.98	86.590	1/2	51.83	213.82
	14.52	16.800		33.37	88.664		52.22	217.07
3/4	14.92	17.720	3/4	33.77	90.762	3/4	52.62	220.35
	15.31	18.665		34.16	92.885		53.01	223.65

Dia.	Circ.	Area.	Dia.	Circ.	Area.	Dia.	Circ.	Area.
17	53.40	226.98	23	72.25	415.47	29	91.10	660.52
	53.79	230.33		72.64	420.00		91.49	666.22
¼	54.19	233.70	¼	73.04	424.55	¼	91.89	671.95
	54.58	237.10		73.43	429.13		92.28	677.71
½	54.97	240.52	½	73.82	433.73	½	92.67	683.49
	55.37	243.97		74.21	438.30		93.06	689.29
¾	55.76	247.45	¾	74.61	443.01	¾	93.46	695.12
	56.16	250.94		75.	447.69		93.85	700.98
18	56.54	254.46	24	75.39	452.39	30	94.24	706.86
	56.94	258.01		75.79	457.11		94.64	712.76
¼	57.33	261.58	¼	76.18	461.86	¼	95.03	718.69
	57.72	265.18		76.57	466.63		95.42	724.64
½	58.11	268.80	½	76.96	471.43	½	95.81	730.61
	58.51	272.44		77.36	476.25		96.21	736.61
¾	58.90	276.11	¾	77.75	481.10	¾	96.60	742.64
	59.29	279.81		78.14	485.97		96.99	748.69
19	59.69	283.52	25	78.54	490.87	31	97.38	754.76
	60.08	287.27		78.93	495.79		97.78	760.86
¼	60.47	291.03	¼	79.32	500.74	¼	98.17	766.99
	60.86	294.83		79.71	505.71		98.56	773.14
½	61.26	298.64	½	80.10	510.70	½	98.96	779.31
	61.65	302.48		80.50	515.72		99.35	785.51
¾	62.04	306.35	¾	80.89	520.70	¾	99.74	791.73
	62.43	310.24		81.28	525.83		100.1	797.97
20	62.83	314.16	26	81.68	530.93	32	100.5	804.24
	63.22	318.09		82.07	536.04		100.9	810.54
¼	63.61	322.06	¼	82.46	541.18	¼	101.3	816.86
	64.01	326.05		82.85	546.35		101.7	823.21
½	64.40	330.06	½	83.25	551.54	½	102.1	829.57
	64.79	334.10		83.64	556.76		102.4	835.97
¾	65.18	338.16	¾	84.03	562.00	¾	102.8	842.39
	65.58	342.25		84.43	567.26		103.2	848.83
21	65.97	346.36	27	84.82	572.55	33	103.6	855.30
	66.36	350.49		85.21	577.87		104.	861.79
¼	66.75	354.65	¼	85.60	583.20	¼	104.4	868.30
	67.15	358.84		86.	588.57		104.8	874.84
½	67.54	363.05	½	86.39	593.95	½	105.2	881.41
	67.93	367.28		86.78	599.37		105.6	888.00
¾	68.32	371.54	¾	87.17	604.80	¾	106.	894.61
	68.72	375.82		87.57	610.26		106.4	901.25
22	69.11	380.13	28	87.96	615.75	34	106.8	907.92
	69.50	384.46		88.35	621.26		107.2	914.61
¼	69.90	388.82	¼	88.75	626.79	¼	107.5	921.32
	70.29	393.20		89.14	632.35		107.9	928.06
½	70.68	397.60	½	89.53	637.94	½	108.3	934.82
	71.07	402.03		89.92	643.54		108.7	941.60
¾	71.47	406.49	¾	90.32	649.18	¾	109.1	948.41
	71.86	410.97		90.71	654.83		109.5	955.25

Dia.	Circ.	Area.	Dia.	Circ.	Area.	Dia.	Circ.	Area.
35	109.9	962.11	41	128.8	1320.2	47	147.6	1734.9
	110.3	968.99		129.1	1328.3		148.	1744.1
¼	110.7	975.90	¼	129.5	1336.4	¼	148.4	1753.4
	111.1	982.84		129.9	1344.5		148.8	1762.7
½	111.5	989.80	½	130.3	1352.6	½	149.2	1772.0
	111.9	996.78		130.7	1360.8		149.6	1781.3
¾	112.3	1003.7	¾	131.1	1369.0	¾	150.	1790.7
	112.7	1010.8		131.5	1377.2		150.4	1800.1
36	113.	1017.8	42	131.9	1385.4	48	150.7	1809.5
	113.4	1024.9		132.3	1393.7		151.1	1818.9
¼	113.8	1032.0	¼	132.7	1401.9	¼	151.5	1828.4
	114.2	1039.1		133.1	1410.2		151.9	1837.9
½	114.6	1046.3	½	133.5	1418.6	½	152.3	1847.4
	115.	1053.5		133.9	1426.9		152.7	1856.9
¾	115.4	1060.7	¾	134.3	1435.3	¾	153.1	1866.5
	115.8	1067.9		134.6	1443.7		153.5	1876.1
37	116.2	1075.2	43	135.	1452.2	49	153.9	1885.7
	116.6	1082.4		135.4	1460.6		154.3	1895.3
¼	117.	1089.7	¼	135.8	1469.1	¼	154.7	1905.0
	117.4	1097.1		136.2	1477.6		155.1	1914.7
½	117.8	1104.4	½	136.6	1486.1	½	155.5	1924.4
	118.2	1111.8		137.	1494.7		155.9	1934.1
¾	118.6	1119.2	¾	137.4	1503.3	¾	156.2	1943.9
	118.9	1126.6		137.8	1511.9		156.6	1953.6
38	119.3	1134.1	44	138.2	1520.5	50	157.	1963.5
	119.7	1141.5		138.6	1529.1		157.4	1973.3
¼	120.1	1149.0	¼	139.	1537.8	¼	157.8	1983.1
	120.5	1156.6		139.4	1546.5		158.2	1993.0
½	120.9	1164.1	½	139.8	1555.2	½	158.6	2002.9
	121.3	1171.7		140.1	1564.0		159.	2012.8
¾	121.7	1179.3	¾	140.5	1572.8	¾	159.4	2022.8
	122.1	1186.9		140.9	1581.6		159.8	2032.8
39	122.5	1194.5	45	141.3	1590.4	51	160.2	2042.8
	122.9	1202.2		141.7	1599.2		160.6	2052.8
¼	123.3	1209.9	¼	142.1	1608.1	¼	161.	2062.9
	123.7	1217.6		142.5	1617.0		161.3	2072.9
½	124.	1225.4	½	142.9	1625.9	½	161.7	2083.0
	124.4	1233.1		143.3	1634.9		162.1	2093.2
¾	124.8	1240.9	¾	143.7	1643.8	¾	162.5	2103.3
	125.2	1248.7		144.1	1652.8		162.9	2113.5
40	125.6	1256.6	46	144.5	1661.9	52	163.3	2123.7
	126.	1264.5		144.9	1670.9		163.7	2133.9
¼	126.4	1272.3	¼	145.2	1680.0	¼	164.1	2144.1
	126.8	1280.3		145.6	1689.1		164.5	2154.4
½	127.2	1288.2	½	146.	1698.2	½	164.9	2164.7
	127.6	1296.2		146.4	1707.3		165.3	2175.0
¾	128.	1304.2	¾	146.8	1716.5	¾	165.7	2185.4
	128.4	1312.2		147.2	1725.7		166.1	2195.7

Dia.	Circ.	Area.	Dia.	Circ.	Area.	Dia.	Circ.	Area.
53	166.5	2206.1	59	185.3	2733.9	65	204.2	3318.3
	166.8	2216.6		185.7	2745.5		204.5	3331.0
¼	167.2	2227.0	¼	186.1	2757.1	¼	204.9	3343.8
	167.6	2237.5		186.5	2768.8		205.3	3356.7
½	168.	2248.0	½	186.9	2780.5	½	205.7	3369.5
	168.4	2258.5		187.3	2792.2		206.1	3382.4
¾	168.8	2269.0	¾	187.7	2803.9	¾	206.5	3395.3
	169.2	2279.6		188.1	2815.6		206.9	3408.2
54	169.6	2290.2	60	188.4	2827.4	66	207.3	3421.2
	170.	2300.8		188.8	2839.2		207.7	3434.1
¼	170.4	2311.4	¼	189.2	2851.0	¼	208.1	3447.1
	170.8	2322.1		189.6	2862.8		208.5	3460.1
½	171.2	2332.8	½	190.	2874.7	½	208.9	3473.2
	171.6	2343.5		190.4	2886.6		209.3	3486.3
¾	172.	2354.2	¾	190.8	2898.5	¾	209.7	3499.3
	172.3	2365.0		191.2	2910.5		210.	3512.5
55	172.7	2375.8	61	191.6	2922.4	67	210.4	3525.6
	173.1	2386.6		192.	2934.4		210.8	3538.8
¼	173.5	2397.4	¼	192.4	2946.4	¼	211.2	3552.0
	173.9	2408.3		192.8	2958.5		211.6	3565.2
½	174.3	2419.2	½	193.2	2970.5	½	212.	3578.4
	174.7	2430.1		193.6	2982.6		212.4	3591.7
¾	175.1	2441.0	¾	193.9	2994.7	¾	212.8	3605.0
	175.5	2452.0		194.3	3006.9		213.2	3618.3
56	175.9	2463.0	62	194.7	3019.0	68	213.6	3631.6
	176.3	2474.0		195.1	3031.2		214.	3645.0
¼	176.7	2485.0	¼	195.5	3043.4	¼	214.4	3658.4
	177.1	2496.1		195.9	3055.7		214.8	3671.8
½	177.5	2507.1	½	196.3	3067.9	½	215.1	3685.2
	177.8	2518.2		196.7	3080.2		215.5	3698.7
¾	178.2	2529.4	¾	197.1	3092.5	¾	215.9	3712.2
	178.6	2540.5		197.5	3104.8		216.3	3725.7
57	179.	2551.7	63	197.9	3117.2	69	216.7	3739.2
	179.4	2562.9		198.3	3129.6		217.1	3752.8
¼	179.8	2574.1	¼	198.7	3142.0	¼	217.5	3766.4
	180.2	2585.4		199.	3154.4		217.9	3780.0
½	180.6	2596.7	½	199.4	3166.9	½	218.3	3793.6
	181.	2608.0		199.8	3179.4		218.7	3807.3
¾	181.4	2619.3	¾	200.2	3191.9	¾	219.1	3821.0
	181.8	2630.7		200.6	3204.4		219.5	3834.7
58	182.2	2642.0	64	201.	3216.9	70	219.9	3848.4
	182.6	2653.4		201.4	3229.5		220.3	3862.2
¼	182.9	2664.9	¼	201.8	3242.1	¼	220.6	3875.9
	183.3	2676.3		202.2	3254.8		221.	3889.8
½	183.7	2687.8	½	202.6	3267.4	½	221.4	3903.6
	184.1	2699.3		203.	3280.1		221.8	3917.4
¾	184.5	2710.8	¾	203.4	3292.8	¾	222.2	3931.3
	184.9	2722.4		203.8	3305.5		222.6	3945.2

Dia.	Circ.	Area.	Dia.	Circ.	Area.	Dia.	Circ.	Area.
71	223.	3959.2	77	241.9	4656.6	83	260.7	5410.6
	223.4	3973.1		242.2	4671.7		261.1	5426.9
¼	223.8	3987.1	¼	242.6	4686.9	¼	261.5	5443.2
	224.2	4001.1		243.	4702.1		261.9	5459.6
½	224.6	4015.1	½	243.4	4717.3	½	262.3	5476.0
	225.	4029.2		243.8	4732.5		262.7	5492.4
¾	225.4	4043.2	¾	244.2	4747.7	¾	263.1	5508.8
	225.8	4067.3		244.6	4763.0		263.5	5525.3
72	226.1	4071.5	78	245.	4778.3	84	263.8	5541.7
	226.5	4085.6		245.4	4793.7		264.2	5558.2
¼	226.9	4099.8	¼	245.8	4809.0	¼	264.6	5574.8
	227.3	4114.0		246.2	4824.4		265.	5591.3
½	227.7	4128.2	½	246.6	4839.8	½	265.4	5607.9
	228.1	4142.5		247.	4855.2		265.8	5624.5
¾	228.5	4156.7	¾	247.4	4870.7	¾	266.2	5641.1
	228.9	4171.0		247.7	4886.1		266.6	5657.8
73	229.3	4185.3	79	248.1	4901.6	85	267.	5674.5
	229.7	4199.7		248.5	4917.2		267.4	5691.2
¼	230.1	4214.1	¼	248.9	4932.7	¼	267.8	5707.9
	230.5	4228.5		249.3	4948.3		268.2	5724.6
½	230.9	4242.9	½	249.7	4963.9	½	269.6	5741.4
	231.3	4257.3		250.1	4979.5		268.9	5758.2
¾	231.6	4271.8	¾	250.5	4995.1	¾	269.3	5775.0
	232.	4286.3		250.9	5010.8		269.7	5791.9
74	232.4	4300.8	80	251.3	5026.5	86	270.1	5808.8
	232.8	4315.3		251.7	5042.2		270.5	5825.7
¼	233.2	4329.9	¼	252.1	5058.0	¼	270.9	5842.6
	233.6	4344.5		252.5	5073.7		271.3	5859.5
½	234.	4359.1	½	252.8	5089.5	½	271.7	5876.5
	234.4	4373.8		253.2	5105.4		272.1	5893.5
¾	234.8	4388.4	¾	253.6	5121.2	¾	272.5	5910.5
	235.2	4403.1		254.	5137.1		272.9	5927.6
75	235.6	4417.8	81	254.4	5153.0	87	273.3	5944.6
	236.	4432.6		254.8	5168.9		273.7	5961.7
¼	236.4	4447.3	¼	255.2	5184.8	¼	274.1	5978.9
	236.7	4462.1		255.6	5200.8		274.4	5996.0
½	237.1	4476.9	½	256.	5216.8	½	274.8	6013.2
	237.5	4491.8		256.4	5232.8		275.2	6030.4
¾	237.9	4506.6	¾	256.8	5248.8	¾	275.6	6047.6
	238.3	4521.5		257.2	5264.9		276.	6064.8
76	238.7	4536.4	82	257.6	5281.0	88	276.4	6082.1
	239.1	4551.4		258.	5297.1		276.8	6099.4
¼	239.5	4566.3	¼	258.3	5313.2	¼	277.2	6116.7
	239.9	4581.3		258.7	5329.4		277.6	6134.0
½	240.3	4596.3	½	259.1	5345.6	½	278.	6151.4
	240.7	4611.3		259.5	5361.8		278.4	6168.8
¾	241.1	4626.4	¾	259.9	5378.0	¾	278.8	6186.2
	241.5	4641.5		260.3	5394.3		279.2	6203.6

Dia.	Circ.	Area.	Dia.	Circ.	Area.	Dia.	Circ.	Area.
89	279.6	6221.1	93	292.1	6792.9	97	304.7	7389.8
	279.9	6238.6		292.5	6811.1		305.1	7408.8
¼	280.3	6256.1	¼	292.9	6829.4	¼	305.5	7427.9
	280.7	6273.6		293.3	6847.8		305.9	7447.0
½	281.1	6291.2	½	293.7	6866.1	½	306.3	7466.2
	281.5	5308.8		294.1	6884.5		306.6	7485.3
¾	281.9	6326.4	¾	294.5	6902.9	¾	307.	7504.5
	282.3	6344.0		294.9	6921.3		307.4	7523.7
90	282.7	6361.7	94	295.3	6939.7	98	307.8	7542.9
	283.1	6379.4		295.7	6958.2		308.2	7562.2
¼	283.5	6397.1	¼	296.	6976.7	¼	308.6	7581.5
	283.9	6414.8		296.4	6995.2		309.0	7600.8
½	284.3	6432.6	½	296.8	7013.8	½	309.4	7620.1
	284.7	6450.4		297.2	7032.3		309.8	7639.4
¾	285.1	6468.2	¾	297.6	7050.9	¾	310.2	7658.8
	285.4	6486.0		298.	7069.5		310.6	7678.2
91	285.8	6503.8	95	298.4	7088.2	99	311.0	7697.7
	286.2	6521.7		298.8	7106.9		311.4	7717.1
¼	286.6	6539.6	¼	299.2	7125.5	¼	311.8	7736.6
	287.	6557.6		299.6	7144.3		312.1	7756.1
½	287.4	6575.5	½	300.	7163.0	½	312.5	7775.6
	287.8	6593.5		300.4	7181.8		312.9	7795.2
¾	288.2	6611.5	¾	300.8	7200.5	¾	313.3	7814.7
	288.6	6629.5		301.2	7219.4		313.7	7834.3
92	289.	6647.6	96	301.5	7238.2	100	314.1	7853.9
	289.4	6665.7		301.9	7257.1		314.5	7853.6
¼	289.8	6683.8	¼	302.3	7275.9	¼	314.9	7893.3
	290.2	6701.9		302.7	7294.9		315.3	7913.1
½	290.5	6720.0	½	303.1	7313.8	½	315.7	7932.7
	290.9	6738.2		303.5	7332.8		316.0	7942.4
¾	291.3	6756.4	¾	303.9	7351.7	¾	316.4	7972.2
	291.7	6776.4		304.3	7370.7		316.8	7991.9

CORROSION OF IRON IN WATER.

Whether the effect of cold on iron is to make it brittle may still be a disputed point; but it seems to be well established that the commonly received opinion that iron must corrode when exposed to moisture is a fallacy. The most careful observations and thorough analysis have convinced scientific men that it is the quality of the iron which determines the question whether or not it will corrode in water—the corrosion depending on the homogeneous surface of the metal. This is the judgment pronounced by the London Institute of Civil Engineers, and is supported by numerous examples of a very striking character. Gray iron having a good surface is used very largely for piles in

submarine works and is proof against decay in salt water; and a leading ship-builder, Mr. Webb, holds that strong iron of proper quality will resist the action of salt water for an indefinite period. Cannon sunk at Lake Erie during the war of 1812 were taken up forty years after almost uninjured. Three iron gates at Sheerness resisted the action of salt water forty years, and a fourth was injured only by galvanic action caused by contact with a lead facing. Cast iron piles at Margate were taken up after standing twenty-two years and sold for the same price as new pig, being equally sound; and other piles left standing are still uninjured, after thirty-eight years' exposure.

It is a common practice to use cheap material in the construction of gas and water pipes, whereas the best should always be employed. The poorer quality, being soft, open-grain and showing large crystals, is found, when taken up, to be oxydized in tubercular knobs. On the other hand, when the pipes of the Manhattan Water Company of New York were taken up in 1860, many of them were found in as sound a state as when they left the foundry in 1820, a period of forty years having elapsed.

DISEASES OF BRAN-FED HORSES.

Millers' horses are particularly subject to a stony secretion in the bowels, caused by eating too much bran. Bran is a very valuable food in a stable for reducing the inflammatory effect of oats and beans. Made into mashes, it has a cooling and laxative effect; but used in excess, especially in a dry state, it is apt to form stony secretions as stated. Stones produced from the excessive use of bran have been taken out of horses after death, weighing many pounds. When sawn through, they appear to be composed of a hard, crystalline mass, deposited in regular annular rings, resembling in appearance the concentric yearly rings of wood; they prove to be composed of phosphate of magnesia, and ammonia. The best way to guard against it is to add half a pint of linseed, boiled until quite soft, to the mash of each horse.

A RELIABLE PASTE.

The following recipe is given for making paste, of such superior quality, it is said, that it will keep twelve months, will adhere better than gum, will not gloss the paper, and can be written on: Having dissolved a teaspoonful of alum in a quart of warm water, let it stand till cold, then stir in enough flour to give it the consistency of thick cream, beat all the lumps up carefully, and stir in as much powdered rosin as will lie on a dime. Half a dozen cloves thrown in will give an agreeable odor. The mixture is now poured into a cup of boiling water, stirring it actively meanwhile, until in a few minutes it becomes as thick as mush. It should then be suffered to cool, and kept covered up in a cool place. When wanted for use, take out a portion and soften with warm water.

THE LENGTH OF SASH-WEIGHTS.

The following table will be found useful in the making of sash-weights, which of course must balance accurately the weight of the sash. The first column of figures indicates the diameter of the round weight or the length of one side of the square weight, in inches and fractional parts of an inch. The other two columns are sufficiently explained in the head lines. Windows of dwelling houses and all classes of public buildings are now so generally made with box frames for the reception of weights and pulleys, that the manufacture of the weights is quite an important branch of industry. It is a very troublesome one in some cases, especially where a job of this kind is only occasionally called for, and the workman is obliged to make an intricate calculation for each new size of weight required.

Diameter.	Length of 1 lb. in inches.	Length of 1 lb. in inches.	Diameter.	Length of 1 lb. in inches.	Length of 1 lb. in inches.
	ROUND IRON.	SQUARE IRON.		ROUND IRON.	SQUARE IRON.
1/2	19.67	15.38	2 3/8	.86	.68
5/8	12.63	9.83	2 1/2	.78	.60
3/4	8.69	6.85	2 5/8	.70	.55
7/8	6.41	5.02	2 3/4	.64	.50
1	4.44	3.84	2 7/8	.59	.46
1 1/8	3.87	3.03	3	.54	.42
1 1/4	3.13	2.45	3 1/8	.50	.39
1 3/8	2.58	2.03	3 1/4	.46	.36
1 1/2	2.17	1.70	3 3/8	.42	.33
1 5/8	1.85	1.45	3 1/2	.39	.31
1 3/4	1.59	1.25	3 5/8	.37	.29
1 7/8	1.39	1.09	3 3/4	.34	.27
2	1.22	.96	3 7/8	.32	.25
2 1/8	1.08	.85	4	.30	.24
2 1/4	.96	.75			

To obtain the length of the weight, it is only necessary to multiply the length of one pound in inches by the number of pounds which the weight is to balance.

TO PREVENT LOOSENING OF SCREWS.

To prevent screws from working loose in the wood, it will be found expedient, before driving the screw, to insert in the hole a stick of about

half its diameter which has been immersed in thick glue. The screw is then driven home as rapidly as possible. In mending furniture, when glue cannot be easily obtained, powdered resin will serve in its place, the stick being inserted in the hole and the resin filled in around it. The stick is then withdrawn and the screw heated sufficiently to melt the resin as it is driven to its place.

To PREVENT the tire of a wagon-wheel from coming loose and requiring to be refitted, a method highly recommended is to fill the felloes with linseed oil before the tire is put on. The timber thus treated is not liable to injury by water, and lasts much longer. The process followed is to hang the wheel in the oil, each felloe being immersed for one hour. The oil, which is contained in a cast-iron heater of suitable length, is brought to a boiling heat—a higher degree must be avoided, or the wood will be burned. The timber should be dry, as in a green state, it will not take oil. The tire of a wheel thus treated will, it is said, wear out before becoming loose.

INTEREST TABLE.

AT FIVE, SIX, SEVEN AND EIGHT PER CENT.—BY DAYS AND MONTHS, FROM ONE DOLLAR TO ONE THOUSAND.

By the following table the interest on any sum of money, for any length of time, at either five, six, seven or eight per cent., may be readily ascertained. In the left-hand column on each page are given the days or months, and for each sum of money for which interest is to be computed there are four columns, one for each rate per cent.

EXAMPLES.

To find the interest on $700 for 1 year, 8 months and 11 days, at 7 per cent. per annum:

700 Dollars, 7 per cent., 12 months, is	$ 49 00
" " " 8 months, "	32 67
" " " 11 days "	1 50
Answer required	$ 83 17

To find the interest on $1508 for 7 months, at 8 per cent.

1000 dollars, 8 per cent., 7 months, is	$ 46 67
500 " " " " "	23 33
8 " " " " "	37
Answer required	$ 70 37

A calculation of interest made by any other method may be readily tested as to its correctness by the use of this table, thus insuring the speedy detection of any mistake.

INTEREST TABLE, AT FIVE, SIX, SEVEN AND EIGHT PER CENT.

BY DAYS AND MONTHS, FROM ONE DOLLAR TO ONE THOUSAND.

Number of Days.	1 dollar.				2 dollars.				3 dollars.				4 dollars.				5 dollars.				6 dollars.			
	Rates per Centum.				Rates per Centum.				Rates per Centum.				Rates per Centum.				Rates per Centum.				Rates per Centum.			
	5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8
	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1
8	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1
9	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
13	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
14	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	2	2
15	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	2	2
16	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	1	1	2	2	1	2	2	2
17	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	1	1	2	2	1	2	2	2
18	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	1	2	2	2	2	2	2	2
19	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	1	2	2	2	2	2	2	2
20	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	1	2	2	2	2	2	2	3
21	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	1	2	2	2	2	2	2	3
22	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	3	3
23	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	2	2	3	3
24	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	2	2	3	3
25	0	0	0	1	1	1	1	1	1	1	1	2	1	2	2	2	2	2	2	3	2	3	3	3
26	0	0	0	1	1	1	1	1	1	1	2	2	1	2	2	2	2	2	3	3	2	3	3	3
27	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	2	3	3	4
28	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	3	2	2	3	3	2	3	3	4
29	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	3	2	2	3	3	2	3	3	4
30	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	2	3	3	3	2	3	3	4
Months.																								
1	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	2	3	3	3	3	3	4	4
2	1	1	1	1	2	2	2	3	3	3	4	4	3	4	5	5	4	5	6	7	5	6	7	8
3	1	2	2	2	3	3	4	4	4	5	5	6	5	6	7	8	6	8	9	10	8	9	11	12
4	2	2	2	3	3	4	5	5	5	6	7	8	7	8	9	11	8	10	12	13	10	12	14	16
5	2	3	3	3	4	5	6	7	6	8	9	10	8	10	12	13	10	13	15	17	13	15	18	20
6	3	3	4	4	5	6	7	8	8	9	11	12	10	12	14	16	13	15	18	20	15	18	21	24
7	3	4	4	5	6	7	8	9	9	11	12	14	12	14	17	19	15	18	20	23	18	21	25	28
8	3	4	5	5	7	8	9	11	10	12	14	16	13	16	19	21	17	20	23	27	20	24	28	32
9	4	5	5	6	8	9	11	12	11	14	16	18	15	18	21	24	19	23	26	30	22	27	32	36
10	4	5	6	7	8	10	12	13	13	15	18	20	17	20	23	27	21	25	29	33	25	30	35	40
11	5	6	6	7	9	11	13	15	14	17	19	22	18	22	26	29	23	28	32	37	28	33	39	44
12	5	6	7	8	10	12	14	16	15	18	21	24	20	24	28	32	25	30	35	40	30	36	42	48

INTEREST TABLE, AT FIVE, SIX, SEVEN AND EIGHT PER CENT.

BY DAYS AND MONTHS, FROM ONE DOLLAR TO ONE THOUSAND.

Number of days.	7 dollars.				8 dollars.				9 dollars.				10 dollars.				20 dollars.			
	Rates per Centum.				Rates per Centum.				Rates per Centum.				Rates per Centum.				Rates per Centum.			
	5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8
	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	cts	$ cts.	$ cts.	$ cts.	$ cts.
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00	00	00	00
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01	01	01	01
3	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	1	01	01	01	01
4	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	01	01	02	02
5	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	01	02	02	02
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	02	02	02	03
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	02	02	03	03
8	1	1	1	1	1	1	1	1	1	1	1	2	1	1	2	2	02	03	03	04
9	1	1	1	1	1	1	1	2	1	1	2	2	1	2	2	2	03	03	04	04
10	1	1	1	2	1	1	2	2	1	2	2	2	1	2	2	2	03	03	04	04
11	1	1	2	2	1	1	2	2	1	2	2	2	2	2	2	2	03	04	04	05
12	1	1	2	2	1	2	2	2	2	2	2	2	2	2	2	3	03	04	05	05
13	1	2	2	2	1	2	2	2	2	2	2	3	2	2	2	3	04	04	05	06
14	1	2	2	2	2	2	2	2	2	2	2	3	2	2	3	3	04	05	05	06
15	1	2	2	2	2	2	2	3	2	2	3	3	2	3	3	3	04	05	06	07
16	2	2	2	2	2	2	3	3	2	2	3	3	2	3	3	4	04	05	06	07
17	2	2	2	3	2	2	3	3	2	3	3	3	2	3	3	4	05	06	07	08
18	2	2	2	3	2	2	3	3	2	3	3	4	3	3	3	4	05	06	07	08
19	2	2	3	3	2	3	3	3	2	3	3	4	3	3	4	4	05	06	07	08
20	2	2	3	3	2	3	3	4	3	3	4	4	3	3	4	4	06	07	08	09
21	2	2	3	3	2	3	3	4	3	3	4	4	3	4	4	5	06	07	08	09
22	2	3	3	3	2	3	3	4	3	3	4	4	3	4	4	5	06	07	09	10
23	2	3	3	3	3	3	4	4	3	3	4	5	3	4	4	5	06	08	09	10
24	2	3	3	4	3	3	4	4	3	4	4	5	3	4	4	5	07	08	09	11
25	2	3	3	4	3	3	4	4	3	4	4	5	3	4	5	6	07	08	10	11
26	3	3	4	4	3	3	4	5	3	4	5	5	4	4	5	6	07	09	10	12
27	3	3	4	4	3	4	4	5	3	4	5	5	4	5	5	6	08	09	11	12
28	3	3	4	4	3	4	4	5	4	4	5	6	4	5	5	6	08	09	11	12
29	3	3	4	5	3	4	5	5	4	4	5	6	4	5	5	6	08	10	11	13
30	3	3	4	5	3	4	5	5	4	5	5	6	4	5	6	7	08	10	12	13
Months.																				
1	3	4	4	5	3	4	5	5	4	5	5	6	4	5	6	7	08	10	12	13
2	6	7	8	9	7	8	9	11	8	9	11	12	8	10	12	13	17	20	23	27
3	9	11	12	14	10	12	14	16	11	14	16	18	13	15	18	20	25	30	35	40
4	12	14	16	19	13	16	19	21	15	18	21	24	17	20	23	27	33	40	47	53
5	15	18	20	23	17	20	23	27	19	23	26	30	21	25	29	33	42	50	58	67
6	18	21	25	28	20	24	28	32	23	27	32	36	25	30	35	40	50	60	70	80
7	20	25	29	33	23	28	33	37	26	32	37	42	29	35	41	47	58	70	82	93
8	23	28	33	37	27	32	37	43	30	36	42	48	33	40	47	53	67	80	93	1·07
9	26	32	37	42	30	36	42	48	34	41	47	54	38	45	53	60	75	90	1·05	1·20
10	29	35	41	47	33	40	47	53	38	45	53	60	42	50	58	67	83	1·00	1.17	1·33
11	32	39	45	51	37	44	51	59	41	50	58	66	46	55	64	73	92	1.10	1.28	1.47
12	35	42	49	56	40	48	56	64	45	54	63	72	50	60	70	80	1.00	1.20	1.40	1.60

INTEREST TABLE, AT FIVE, SIX, SEVEN AND EIGHT PER CENT.

BY DAYS AND MONTHS, FROM ONE DOLLAR TO ONE THOUSAND.

Number of days.	30 dollars.				40 dollars.				50 dollars.				60 dollars.			
	Rates per Centum.				Rates per Centum.				Rates per Centum.				Rates per Centum.			
	5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8
	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts
1	00	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
2	01	01	01	01	01	01	02	02	01	02	02	02	02	02	02	03
3	01	02	02	02	02	02	02	03	02	03	03	03	03	03	04	04
4	02	02	02	03	02	03	03	04	03	03	04	04	03	04	05	05
5	02	03	03	03	03	03	04	04	03	04	05	06	04	05	06	07
6	03	03	04	04	03	04	05	05	04	05	06	07	05	06	07	08
7	03	04	04	05	04	05	05	06	05	06	07	08	06	07	08	09
8	03	04	05	05	04	05	06	07	06	07	08	09	07	08	09	11
9	04	05	05	06	05	06	07	08	06	08	09	10	08	09	11	12
10	04	05	06	07	06	07	08	09	07	08	10	11	08	10	12	13
11	05	06	06	07	06	07	09	10	08	09	11	12	09	11	13	15
12	05	06	07	08	07	08	09	11	08	10	12	13	10	12	14	16
13	05	07	08	09	07	09	10	12	09	11	13	14	11	13	15	17
14	06	07	08	09	08	09	11	12	10	12	14	16	12	14	16	19
15	06	08	09	10	08	10	12	13	10	13	15	17	13	15	18	20
16	07	08	09	11	09	11	12	14	11	13	16	18	13	16	19	21
17	07	09	10	11	09	11	13	15	12	14	17	19	14	17	20	23
18	08	09	11	12	10	12	14	16	13	15	18	20	15	18	21	24
19	08	10	11	13	11	13	15	17	13	16	18	21	16	19	22	25
20	08	10	12	13	11	13	16	18	14	17	19	22	17	20	23	27
21	09	11	12	14	12	14	16	19	15	18	20	23	18	21	25	28
22	09	11	13	15	12	15	17	20	15	18	21	24	18	22	26	29
23	10	12	13	15	13	15	18	20	16	19	22	26	19	23	27	31
24	10	12	14	16	13	16	19	21	17	20	23	27	20	24	28	32
25	10	13	15	17	14	17	19	22	17	21	24	28	21	25	29	33
26	11	13	15	17	14	17	20	23	18	22	25	29	22	26	30	35
27	11	14	16	18	15	18	21	24	19	23	26	30	23	27	32	36
28	12	14	16	19	16	19	22	25	19	23	27	31	23	28	33	37
29	12	15	17	19	16	19	23	26	20	24	28	32	24	29	34	39
30	13	15	18	20	17	20	23	27	21	25	29	33	25	30	35	40
Months.																
1	13	15	18	20	17	20	23	27	21	25	29	33	25	30	35	40
2	25	30	35	40	33	40	47	53	42	50	58	67	50	60	70	80
3	38	45	53	60	50	60	70	80	63	75	88	1.00	75	90	1.05	1.20
4	50	60	70	80	67	80	93	1.07	83	1.00	1.17	1.33	1.00	1.20	1.40	1.60
5	63	75	88	1.00	83	1.00	1.17	1.33	1.04	1.25	1.46	1.67	1.25	1.50	1.75	2.00
6	75	90	1.05	1.20	1.00	1.20	1.40	1.60	1.25	1.50	1.75	2.00	1.50	1.80	2.10	2.40
7	88	1.05	1.23	1.40	1.17	1.40	1.63	1.87	1.46	1.75	2.04	2.33	1.75	2.10	2.45	2.80
8	1.00	1.20	1.40	1.60	1.33	1.60	1.87	2.13	1.67	2.00	2.33	2.67	2.00	2.40	2.80	3.20
9	1.13	1.35	1.58	1.80	1.50	1.80	2.10	2.40	1.88	2.25	2.63	3.00	2.25	2.70	3.15	3.60
10	1.25	1.50	1.75	2.00	1.67	2.00	2.33	2.67	2.08	2.50	2.92	3.33	2.50	3.00	3.50	4.00
11	1.38	1.65	1.93	2.20	1.83	2.20	2.57	2.93	2.29	2.75	3.21	3.67	2.75	3.30	3.85	4.40
12	1.50	1.80	2.10	2.40	2.00	2.40	2.80	3.20	2.50	3.00	3.50	4.00	3.00	3.60	4.20	4.80

INTEREST TABLE, AT FIVE, SIX, SEVEN AND EIGHT PER CENT.

BY DAYS AND MONTHS, FROM ONE DOLLAR TO ONE THOUSAND.

Number of days.	70 dollars.				80 dollars.				90 dollars.				100 dollars.			
	Rates per Centum.				Rates per Centum.				Rates per Centum.				Rates per Centum.			
	5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8
	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts	$ cts
1	01	01	01	02	01	01	02	02	01	02	02	02	01	02	02	02
2	02	02	03	03	02	03	03	04	03	03	04	04	03	03	04	04
3	03	04	04	05	03	04	05	05	04	05	05	06	04	05	06	07
4	04	05	05	06	04	05	06	07	05	06	07	08	06	07	08	09
5	05	06	07	08	06	07	08	09	06	08	09	10	07	08	10	11
6	06	07	08	09	07	08	09	11	08	09	11	12	08	10	12	13
7	07	08	10	11	08	09	11	12	09	11	12	14	10	12	14	16
8	08	09	11	12	09	11	12	14	10	12	14	16	11	13	16	18
9	09	11	12	14	10	12	14	16	11	14	16	18	13	15	18	20
10	10	12	14	16	11	13	16	18	13	15	18	20	14	17	19	22
11	11	13	15	17	12	15	17	20	14	17	19	22	15	18	21	24
12	12	14	16	19	13	16	19	21	15	18	21	24	17	20	23	27
13	13	15	18	20	14	17	20	23	16	20	23	26	18	22	25	29
14	14	16	19	22	16	19	22	25	18	21	25	28	19	23	27	31
15	15	18	20	23	17	20	23	27	19	23	26	30	21	25	29	33
16	16	19	22	25	18	21	25	28	20	24	28	32	22	27	31	36
17	17	20	23	26	19	23	26	30	21	26	30	34	24	28	33	38
18	18	21	25	28	20	24	28	32	23	27	32	36	25	30	35	40
19	18	22	26	30	21	25	30	34	24	29	33	38	26	32	37	42
20	19	23	27	31	22	27	31	36	25	30	35	40	28	33	39	44
21	20	25	29	33	23	28	33	37	26	32	37	42	29	35	41	47
22	21	26	30	34	24	29	34	39	28	33	39	44	31	37	43	49
23	22	27	31	36	26	31	36	41	29	35	40	46	32	38	45	51
24	23	28	33	37	27	32	37	43	30	36	42	48	33	40	47	53
25	24	29	34	39	28	33	39	44	31	38	44	50	35	42	49	56
26	25	30	35	40	29	35	40	46	33	39	46	52	36	43	51	58
27	26	32	37	42	30	36	42	48	34	41	47	54	38	45	53	60
28	27	33	38	44	31	37	44	50	35	42	49	56	39	47	54	62
29	28	34	39	45	32	39	45	52	36	44	51	58	40	48	56	64
30	29	35	41	47	33	40	47	53	38	45	53	60	42	50	58	67
Months.																
1	29	35	41	47	33	40	47	53	38	45	53	60	42	50	58	67
2	58	70	82	93	67	80	93	1.07	75	90	1.05	1.20	83	1.00	1.17	1.33
3	88	1.05	1.23	1.40	1.00	1.20	1.40	1.60	1.13	1.35	1.58	1.80	1.25	1.50	1 75	2.00
4	1.17	1.40	1.63	1.87	1.33	1.60	1.87	2.13	1.50	1.80	2.10	2.40	1.67	2.00	2.33	2.67
5	1.46	1.75	2.04	2.33	1.67	2.00	2.33	2.67	1.88	2.25	2.63	3.00	2.08	2.50	2.92	3.33
6	1.75	2.10	2.45	2.80	2.00	2.40	2.80	3.20	2.25	2.70	3.15	3.60	2.50	3.00	3.50	4.00
7	2.04	2.45	2.86	3.27	2.33	2.80	3.27	3.73	2.63	3.15	3.68	4.20	2.92	3.50	4.08	4.67
8	2.33	2.80	3.27	3.73	2.67	3.20	3.73	4.27	3.00	3.60	4.20	4.80	3.33	4.00	4.67	5.33
9	2.63	3.15	3.68	4.20	3.00	3.60	4.20	4.80	3.38	4.05	4.73	5.40	3.75	4.50	5.25	6.00
10	2.92	3.50	4.08	4.67	3.33	4.00	4.67	5.33	3.75	4.50	5.25	6.00	4.17	5.00	5.83	6.67
11	3.21	3.85	4.49	5.13	3.67	4.40	5.13	5.87	4.13	4.95	5.78	6.60	4.58	5.50	6.42	7.33
12	3.50	4.20	4.90	5.60	4.00	4.80	5.60	6.40	4.50	5.40	6.30	7.20	5.00	6.00	7.00	8.00

INTEREST TABLE, AT FIVE, SIX, SEVEN AND EIGHT PER CENT.

BY DAYS AND MONTHS, FROM ONE DOLLAR TO ONE THOUSAND.

Number of days.	200 dollars.				300 dollars.				400 dollars.			
	Rates per Centum.				Rates per Centum.				Rates per Centum.			
	5	6	7	8	5	6	7	8	5	6	7	8
	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
1	03	03	04	04	04	05	06	07	06	07	08	09
2	06	07	08	09	08	10	12	13	11	13	16	18
3	08	10	12	13	13	15	18	20	17	20	23	27
4	11	13	16	18	17	20	23	27	22	27	31	36
5	14	17	19	22	21	25	29	33	28	33	39	44
6	17	20	23	27	25	30	35	40	33	40	47	53
7	19	23	27	31	29	35	41	47	39	47	54	62
8	22	27	31	36	33	40	47	53	44	53	62	71
9	25	30	35	40	38	45	53	60	50	60	70	80
10	28	33	39	44	42	50	58	67	56	67	78	89
11	31	37	43	49	46	55	64	73	61	73	86	98
12	33	40	47	53	50	60	70	80	67	80	93	1.07
13	36	43	51	58	54	65	76	87	72	87	1.01	1.16
14	39	47	54	62	58	70	82	93	78	93	1.09	1.24
15	42	50	58	67	63	75	88	1.00	83	1.00	1.17	1.33
16	44	53	62	71	67	80	93	1.07	89	1.07	1.24	1.42
17	47	57	66	76	71	85	99	1.13	95	1.13	1.32	1.51
18	50	60	70	80	75	90	1.05	1.20	1.00	1.20	1.40	1.60
19	53	63	74	84	79	95	1.11	1.27	1.06	1.27	1.48	1.69
20	56	67	78	89	83	1.00	1.17	1.33	1.11	1.33	1.56	1.78
21	58	70	82	93	88	1.05	1.23	1.40	1.16	1.40	1.63	1.87
22	61	73	86	98	92	1.10	1.28	1.47	1.22	1.47	1.71	1.96
23	64	77	89	1.02	96	1.15	1.34	1.53	1.27	1.53	1.79	2.04
24	67	80	93	1.07	1.00	1.20	1.40	1.60	1.33	1.60	1.87	2.13
25	69	83	97	1.11	1.04	1.25	1.46	1.67	1.38	1.67	1.94	2.22
26	72	87	1.01	1.16	1.08	1.30	1.52	1.73	1.44	1.73	2.02	2.31
27	75	90	1.05	1.20	1.13	1.35	1.58	1.80	1.50	1.80	2.10	2.40
28	78	93	1.09	1.24	1.17	1.40	1.63	1.87	1.55	1.87	2.18	2.49
29	81	97	1.13	1.29	1.21	1.45	1.69	1.93	1.61	1.93	2.26	2.58
30	83	100	1.17	1.33	1.25	1.50	1.75	2.00	1.67	2.00	2.33	2.67
Months.												
1	83	1.00	1.17	1.33	1.25	1.50	1.75	2.00	1.67	2.00	2.33	2.67
2	1.67	2.00	2.33	2.67	2.50	3.00	3.50	4.00	3.33	4.00	4.67	5.33
3	2.50	3.00	3.50	4.00	3.75	4.50	5.25	6.00	5.00	6.00	7.00	8.00
4	3.33	4.00	4.67	5.33	5.00	6.00	7.00	8.00	6.67	8.00	9.33	10.67
5	4.17	5.00	5.83	6.67	6.25	7.50	8.75	10.00	8.33	10.00	11.67	13.33
6	5.00	6.00	7.00	8.00	7.50	9.00	10.50	12.00	10.00	12.00	14.00	16.00
7	5.83	7.00	8.17	9.33	8.75	10.50	12.25	14.00	11.67	14.00	16.33	18.67
8	6.67	8.00	9.33	10.67	10.00	12.00	14.00	16.00	13.33	16.00	18.67	21.33
9	7.50	9.00	10.50	12.00	11.25	13.50	15.75	18.00	15.00	18.00	21.00	24.00
10	8.33	10.00	11.67	13.33	12.50	15.00	17.50	20.00	16.67	20.00	23.33	26.67
11	9.17	11.00	12.83	14.67	13.75	16.50	19.25	22.00	18.33	22.00	25.67	29.33
12	10.00	12.00	14.00	16.00	15.00	18.00	21.00	24.00	20.00	24.00	28.00	32.00

INTEREST TABLE, AT FIVE, SIX, SEVEN AND EIGHT PER CENT.

BY DAYS AND MONTHS, FROM ONE DOLLAR TO ONE THOUSAND.

Number of days.	500 dollars.				600 dollars.				700 dollars.			
	Rates per Centum.				Rates per Centum.				Rates per Centum.			
	5	6	7	8	5	6	7	8	5	6	7	8
	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
1	07	08	10	11	08	10	12	13	10	12	14	16
2	14	17	19	22	17	20	23	27	19	23	27	31
3	21	25	29	33	25	30	35	40	29	35	41	47
4	28	33	39	44	33	40	47	53	39	47	54	62
5	35	42	49	56	42	50	58	67	49	58	68	78
6	42	50	58	67	50	60	70	80	58	70	82	93
7	49	58	68	78	58	70	82	93	68	82	95	1.09
8	56	67	78	89	67	80	93	1.07	78	93	1.09	1.24
9	62	75	87	1.00	75	90	1.05	1.20	87	1.05	1.22	1.40
10	69	83	97	1.11	83	1.00	1.17	1.33	97	1.17	1.36	1.56
11	76	92	1.07	1.22	92	1.10	1.28	1.47	1.07	1.28	1.50	1.71
12	83	1.00	1.17	1.33	1.00	1.20	1.40	1.60	1.17	1.40	1.63	1.87
13	90	1.08	1.26	1.44	1.08	1.30	1.52	1.73	1.26	1.52	1.77	2.02
14	97	1.17	1.36	1.56	1.17	1.40	1.63	1.87	1.36	1.63	1.91	2.18
15	1.04	1.25	1.46	1.67	1.25	1.50	1.75	2.00	1.46	1.75	2.04	2.33
16	1.11	1.33	1.56	1.78	1.33	1.60	1.87	2.13	1.56	1.87	2.18	2.49
17	1.18	1.42	1.65	1.89	1.42	1.70	1.98	2.27	1.65	1.98	2.31	2.64
18	1.25	1.50	1.75	2.00	1.50	1.80	2.10	2.40	1.75	2.10	2.45	2.80
19	1.32	1.58	1.85	2.11	1.58	1.90	2.22	2.53	1.85	2.22	2.59	2.96
20	1.39	1.67	1.94	2.22	1.67	2.00	2.33	2.67	1.94	2.33	2.72	3.11
21	1.46	1.75	2.04	2.33	1.75	2.10	2.45	2.80	2.04	2.45	2.86	3.27
22	1.53	1.83	2.14	2.44	1.83	2.20	2.57	2.93	2.14	2.57	2.99	3.42
23	1.60	1.92	2.24	2.56	1.92	2.30	2.68	3.07	2.24	2.68	3.13	3.58
24	1.67	2.00	2.33	2.67	2.00	2.40	2.80	3.20	2.33	2.80	3.27	3.73
25	1.74	2.08	2.43	2.78	2.08	2.50	2.92	3.33	2.43	2.92	3.40	3.89
26	1.81	2.17	2.53	2.89	2.17	2.60	3.03	3.47	2.53	3.03	3.54	4.04
27	1.87	2.25	2.63	3.00	2.25	2.70	3.15	3.60	2.63	3.15	3.67	4.20
28	1.94	2.33	2.72	3.11	2.33	2.80	3.27	3.73	2.72	3.27	3.81	4.36
29	2.01	2.42	2.82	3.22	2.42	2.90	3.38	3.87	2.82	3.38	3.95	4.51
30	2.08	2.50	2.92	3.33	2.50	3.00	3.50	4.00	2.92	3.50	4.08	4.67
Months.												
1	2.08	2.50	2.92	3.33	2.50	3.00	3.50	4.00	2.92	3.50	4.08	4.67
2	4.17	5.00	5.83	6.67	5.00	6.00	7.00	8.00	5.83	7.00	8.17	9.33
3	6.25	7.50	8.75	10.00	7.50	9.00	10.50	12.00	8.75	10.50	12.25	14.00
4	8.33	10.00	11.67	13.33	10.00	12.00	14.00	16.00	11.67	14.00	16.33	18.67
5	10.42	12.50	14.58	16.67	12.50	15.00	17.50	20.00	14.58	17.50	20.42	23.33
6	12.50	15.00	17.50	20.00	15.00	18.00	21.00	24.00	17.50	21.00	24.50	28.00
7	14.58	17.50	20.42	23.33	17.50	21.00	24.50	28.00	20.42	24.50	28.58	32.67
8	16.67	20.00	23.33	26.67	20.00	24.00	28.00	32.00	23.33	28.00	32.67	37.33
9	18.75	22.50	26.25	30.00	22.50	27.00	31.50	36.00	26.25	31.50	36.75	42.00
10	20.83	25.00	29.17	33.33	25.00	30.00	35.00	40.00	29.17	35.00	40.83	46.67
11	22.92	27.50	32.08	36.67	27.50	33.00	38.50	44.00	32.08	38.50	44.92	51.33
12	25.00	30.00	35.00	40.00	30.00	36.00	42.00	48.00	35.00	42.00	49.00	56.00

INTEREST TABLE, AT FIVE, SIX, SEVEN AND EIGHT PER CENT.

BY DAYS AND MONTHS, FROM ONE DOLLAR TO ONE THOUSAND.

Number of days.	800 dollars.				900 dollars.				1000 dollars.			
	Rates per Centum.				Rates per Centum.				Rates per Centum.			
	5	6	7	8	5	6	7	8	5	6	7	8
	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
1	11	13	16	18	13	15	18	20	14	17	19	22
2	22	27	31	36	25	30	35	40	28	33	39	44
3	33	40	47	53	38	45	53	60	42	50	58	67
4	44	53	62	71	50	60	70	80	56	67	78	89
5	56	67	78	89	63	75	88	1.00	69	83	97	1.11
6	67	80	93	1.07	75	90	1.05	1.20	83	1.00	1.17	1.33
7	78	93	1.09	1.24	88	1.05	1.23	1.40	97	1.17	1.36	1.56
8	89	1.07	1.24	1.42	1.00	1.20	1.40	1.60	1.11	1.33	1.56	1.78
9	1.00	1.20	1.40	1.60	1.13	1.35	1.58	1.80	1.25	1.50	1.75	2.00
10	1.11	1.33	1.56	1.78	1.25	1.50	1.75	2.00	1.39	1.67	1.94	2.22
11	1.22	1.47	1.71	1.96	1.38	1.65	1.93	2.20	1.53	1.83	2.14	2.44
12	1.33	1.60	1.87	2 13	1.50	1.80	2.10	2.40	1.67	2.00	2.33	2.67
13	1.44	1.73	2.02	2.31	1.63	1.95	2.28	2.60	1.81	2.17	2.53	2.89
14	1.56	1.87	2.18	2.49	1.75	2.10	2.45	2.80	1.94	2.33	2.72	3.11
15	1.67	2.00	2.33	2.67	1.88	2.25	2.63	3.00	2.08	2.50	2.92	3.33
16	1.78	2.13	2.49	2.84	2.00	2.40	2.80	3.20	2.22	2.67	3.11	3.56
17	1.89	2.27	2.64	3.02	2.13	2.55	2.98	3.40	2.36	2.83	3.31	3.78
18	2.00	2.40	2.80	3.20	2.25	2.70	3.15	3.60	2.50	3.00	3.50	4.00
19	2 11	2.53	2.96	3.38	2.38	2.85	3.33	3 80	2.64	3.17	3.69	4.22
20	2.22	2.67	3.11	3.56	2.50	3.00	3.50	4.00	2.78	3.33	3.89	4.44
21	2.33	2.80	3.27	3.73	2.63	3.15	3.68	4.20	2.92	3.50	4.08	4.67
22	2.44	2.93	3.42	3.91	2.75	3.30	3.85	4.40	3.06	3.67	4.28	4.89
23	2.56	3.07	3.58	4.09	2.88	3.45	4.03	4.60	3.19	3.83	4.47	5.11
24	2.67	3.20	3.73	4.27	3.00	3.60	4.20	4.80	3.33	4.00	4.67	5.33
25	2.78	3.33	3.89	4.44	3.13	3.75	4.38	5.00	3.47	4.17	4.86	5.56
26	2.89	3.47	4.04	4.62	3.25	3.90	4.55	5.20	3.61	4.33	5.06	5.78
27	3.00	3.60	4.20	4.80	3.38	4.05	4.73	5.40	3.75	4.50	5.25	6.00
28	3.11	3.73	4.36	4.98	3.50	4.20	4.90	5.60	3.89	4.67	5.44	6.22
29	3.22	3.87	4.51	5.16	3.63	4.35	5.08	5.80	4 03	4.83	5.64	6.44
30	3.33	4.00	4.67	5.33	3.75	4.50	5.25	6.00	4.17	5.00	5.83	6.67
Months.												
1	3.33	4.00	4.67	5.33	3.75	4.50	5.25	6.00	4.17	5.00	5.83	6.67
2	6.67	8.00	9.33	10.67	7.50	9.00	10.50	12.00	8.33	10.00	11.67	13.33
3	10.00	12.00	14.00	16.00	11.25	13.50	15.75	18.00	12.50	15.00	17.50	20.00
4	13.33	16.00	18.67	21.33	15.00	18.00	21.00	24.00	16.67	20.00	23.33	26.67
5	16.67	20.00	23.33	26.67	18.75	22.50	26.25	30.00	20.83	25.00	29.17	33.33
6	20.00	24.00	28.00	32.00	22.50	27.00	31.50	36.00	25.00	30.00	35.00	40.00
7	23.33	28.00	32.67	37.33	26.25	31.50	36 75	42.00	29.17	35.00	40.83	46.67
8	26.67	32.00	37.33	42.67	30.00	36.00	42.00	48.00	33.33	40.00	46.67	53.33
9	30.00	36.00	42.00	48.00	33.75	40.50	47.25	54.00	37.50	45.00	52.50	60.00
10	33 33	40.00	46.67	53.33	37.50	45.00	52.50	60.00	41.67	50.00	58.33	66.67
11	36.67	44 00	51.33	58.67	41.25	49.50	57.75	66.00	45.83	55.00	64.17	73.33
12	40.00	48.00	56.00	64.00	45.00	54.00	63.00	72.00	50.00	60.00	70.00	80.00

HOW TO EXAMINE A WELL OR CISTERN.

In order to explore the bottom of a well, cistern or pond of water, to ascertain whether foreign substances and sediment have been deposited which it is desirable to remove, it is not necessary to descend to the place to be examined. If the sun is shining clearly, a common mirror may be so used as to reveal the profoundest secrets of the gloomy depth below. When held so as to reflect the rays of the sun upon the surface of the water, it will produce a bright spot within the limits of which the smallest object, even to a floating straw, can be plainly seen; and by moving the glass so as to change the illuminated spot, the whole bottom may be explored, if not hidden by intervening objects. If the sun does not shine upon the locality of the opening, its rays may be brought to the place by the use of two mirrors or if necessary a series of them, one reflecting the light to the other until it reaches the desired point, when it may be thrown downward. Light may be carried in this way around a house or through it for any distance, the only drawback being that it becomes less brilliant with each reflection. The trouble involved in the experiment is fully compensated by the amusement it affords, as well as by the timely discovery, in many cases, of unwholesome deposits in water which is daily used for domestic purposes.

A STRONG solution of alum and water, applied while hot, will effectually clean a smoky mantle. When dry, it should be sand-papered and receive one coat of paint.

POWER, QUANTITY OF WATER USED, AND REVOLUTIONS OF TURBINE WATER WHEELS.

In the following tables are given the number of horse power, quantity of water used per minute, and number of revolutions per minute, of turbine water wheels of various sizes, under heads ranging from 3 to 40 feet. The tables give the number of revolutions made by the wheel when at work. But as there is always a loss of fall by the water drawing down in the head race and also rising in the tail race, when the wheel is running, the calculations for speed of wheel and machinery should be based on a fall from six inches to a foot less than the measured fall, when the head and fall is from four to twenty feet, and eighteen inches when the fall is over twenty feet; thus allowing for the loss of head mentioned, which will bring the speed of the wheel to suit the actual running head.

The tables here given, seven in number, were calculated and arranged for the Leffel Double Turbine Water Wheel. The sixth and seventh of the series are especially computed for wheels furnishing the power employed in mining operations. The fifth, sixth and seventh tables, it will be observed, are arranged somewhat differently from the others, the heads in these tables ranging from 41 to 100 feet:

POWER, QUANTITY OF WATER USED, AND REVOLUTIONS OF TURBINE WATER WHEELS.

Head.	Size of Wheels.	6¼	7½	8¼	10	11½	13¼	15¼	17½	20	23	26½	30¼
3	Horse Power..	.15	.20	.25	.33	.44	.58	.76	.97	1.3	1.7	2.2	3.0
	Cubic Feet....	29	39	49	67	87	116	151	197	260	347	451	602
	Revolutions...	360	313	273	239	207	180	157	136	119	104	90	78
4	Horse Power..	.22	.30	.38	.52	.67	.90	1.0	1.5	2.0	2.6	3.5	4.6
	Cubic Feet....	33	45	57	77	100	134	174	227	301	401	521	695
	Revolutions...	416	362	315	275	240	208	181	158	138	119	104	90
5	Horse Power..	.31	.42	.53	.72	.94	1.2	1.6	2.1	2.8	3.7	4.8	6.5
	Cubic Feet....	37	50	64	86	112	149	194	254	336	448	583	777
	Revolutions...	465	405	352	308	268	233	202	176	154	134	116	101
6	Horse Power..	.41	.56	.70	.95	1.2	1.6	2.1	2.8	3.7	4.9	6.4	8.5
	Cubic Feet....	41	55	70	94	123	164	213	278	368	491	638	851
	Revolutions...	510	444	386	337	293	255	221	193	169	147	127	111
7	Horse Power..	.52	.70	.88	1.1	1.5	2.0	2.7	3.5	4.6	6.2	8.1	10.8
	Cubic Feet....	44	60	75	102	133	177	230	301	398	531	690	920
	Revolutions...	551	478	417	364	317	275	239	208	182	159	138	120
8	Horse Power..	.63	.86	1.0	1.4	1.9	2.5	3.3	4.3	5.7	7.6	9.0	13.2
	Cubic Feet....	47	64	80	109	144	189	246	321	425	567	737	983
	Revolutions...	588	511	446	390	339	294	256	223	195	169	147	128
9	Horse Power..	.76	1.0	1.2	1.7	2.2	3.0	3.9	5.1	6.8	9.0	11.8	15.7
	Cubic Feet....	50	68	85	115	150	201	261	341	451	602	782	1043
	Revolutions...	624	542	473	414	359	312	271	236	207	180	156	136
10	Horse Power..	.89	1.2	1.5	2.0	2.6	3.5	4.6	6.0	7.9	10.6	13.8	18.4
	Cubic Feet....	53	71	90	122	159	211	275	359	476	634	824	1099
	Revolutions...	658	572	498	436	379	329	286	249	218	190	164	143
11	Horse Power..	1.0	1.3	1.7	2.3	3.0	4.0	5.3	6.9	9.2	12.2	15.9	21.2
	Cubic Feet....	55	75	94	128	166	222	188	377	499	665	864	1153
	Revolutions...	690	600	523	457	397	345	300	261	229	199	173	150
12	Horse Power..	1.1	1.6	1.9	2.6	3.5	4.6	6.0	7.9	10.4	13.9	18.1	24.2
	Cubic Feet....	58	78	98	133	174	232	301	393	521	695	903	1204
	Revolutions..	721	626	546	473	415	360	313	273	239	208	180	157
13	Horse Power..	1.3	1.7	2.2	3.0	3.9	5.2	6.8	8.9	11.8	15.7	20.5	27.3
	Cubic Feet....	60	81	102	139	181	241	313	410	542	723	940	1253
	Revolutions...	750	652	568	497	432	375	326	284	249	217	188	163
14	Horse Power..	1.5	1.9	2.5	3.3	4.4	5.8	7.6	10.0	13.2	17.6	22.9	30.5
	Cubic Feet....	63	84	106	144	188	250	325	425	563	750	975	1300
	Revolutions...	779	677	590	516	448	389	338	295	258	224	195	169
15	Horse Power..	1.6	2.2	2.7	3.7	4.8	6.5	8.4	11.0	14.6	19.5	25.4	33.8
	Cubic Feet....	65	87	110	149	194	259	337	440	582	777	1009	1346
	Revolutions...	806	700	610	534	464	403	350	305	267	232	201	175
16	Horse Power..	1.7	2.4	3.0	4.1	5.3	7.1	9.3	12.2	16.1	21.5	28.0	37.3
	Cubic Feet....	67	90	114	154	201	267	348	455	602	802	1043	1390
	Revolutions...	832	723	630	551	479	416	362	315	276	240	208	181
17	Horse Power..	1.9	2.6	3.3	4.5	5.9	7.8	10.2	13.3	17.6	23.5	30.6	40.8
	Cubic Feet....	69	93	117	159	207	276	358	469	620	827	1075	1433
	Revolutions...	869	745	650	568	494	429	373	325	284	242	214	187
18	Horse Power..	2.1	2.8	3.6	4.9	6.4	8.5	11.1	14.5	19.2	25.7	33.4	44.5
	Cubic Feet....	71	94	121	163	213	284	369	482	638	851	1106	1475
	Revolutions...	883	767	668	585	508	441	384	334	293	254	221	192
19	Horse Power..	2.3	3.1	3.9	5.3	6.9	9.2	12.0	15.7	20.9	27.8	36.2	48.3
	Cubic Feet....	73	98	124	168	219	291	379	495	656	874	1136	1515
	Revolutions...	907	788	687	601	522	454	394	343	300	261	227	197
20	Horse Power..	2.5	3.3	4.2	5.7	7.5	10.0	13.0	17.0	22.5	30.1	39.1	52.1
	Cubic Feet....	75	101	127	172	224	299	489	508	673	897	1166	1554
	Revolutions...	931	809	704	617	536	465	405	352	308	268	233	202
21	Horse Power..	2.7	3.6	4.5	6.2	8.1	10.7	14.0	18.3	24.2	32.3	42.1	56.1
	Cubic Feet....	77	103	130	176	230	306	398	521	689	919	1194	1592
	Revolutions...	954	828	722	632	549	477	414	361	316	275	238	207

POWER, QUANTITY OF WATER USED, AND REVOLUTIONS OF TURBINE WATER WHEELS.

Head.	Size of Wheels.	35	40	44	48	52	56	61	66	74	84	96
3	Horse Power	3.9	5.2	5.9	7.5	9.8	13.1	15.1	18.1	22.0	29.0	37.9
	Cubic Feet	793	1042	1213	1506	1956	2556	3010	3612	4419	5761	7528
	Revolutions	68	60	55	50	44	42	40	36	32	28	25
4	Horse Power	6.1	8.0	9.4	11.6	15.1	19.7	23.3	28.0	34.3	44.7	58.[illegible]
	Cubic Feet	916	1203	1400	1738	2259	2931	3416	4170	5106	6662	8690
	Revolutions	79	69	63	57	53	49	45	40	37	33	29
5	Horse Power	8.5	11.2	13.1	16.3	21.1	27.6	32.6	39.1	47.8	62.4	81.5
	Cubic Feet	2023	1345	1568	1942	2525	3273	3854	4602	5706	7440	9710
	Revloutions	88	77	70	64	60	55	50	44	41	37	32
6	Horse Power	11.2	14.8	17.2	21.4	27.8	36.3	42.8	51.4	62.9	82.0	107.1
	Cubic Feet	1121	1473	1717	2128	2766	3537	4256	5109	6247	8152	10640
	Revolutions	96	84	77	70	65	60	55	47	45	40	35
7	Horse Power	14.2	18.8	21.9	27.0	35.1	45.7	54.0	64.8	79.3	103.4	135.0
	Cubic Feet	1211	1592	1857	2290	2986	3875	4598	5520	6760	8817	11495
	Revolutions	104	91	83	77	70	65	60	50	49	43	38
8	Horse Power	17.3	22.8	26.6	32.9	42.8	55.9	65.9	79.2	96.9	126.4	164.9
	Cubic Feet	1295	1701	1978	2457	3194	4143	4914	5898	7214	9415	12285
	Revolutions	111	97	89	81	76	69	64	54	53	46	41
9	Horse Power	20.7	27.2	31.8	39.3	51.1	66.7	78.7	94.5	115.6	150.8	196.8
	Cubic Feet	1373	1804	2110	2607	3339	4457	5214	6158	7659	9994	13035
	Revolutions	118	103	94	86	80	74	68	58	56	49	43
10	Horse Power	24.3	31.9	37.2	46.1	59.0	78.1	92.2	110.6	135.4	176.7	230.5
	Cubic Feet	1448	1902	2211	2747	2571	4646	5494	6594	8075	10534	13735
	Revolutions	125	109	100	91	86	78	71	63	59	52	46
11	Horse Power	28.0	36.8	45.0	53.2	69.1	90.2	106.4	127.6	156.2	203.8	266.0
	Cubic Feet	1518	1995	2324	2882	3740	4857	5764	7783	8472	11057	14410
	Revolutions	132	114	104	95	90	82	75	67	62	54	48
12	Horse Power	31.[illegible]	41.9	49.3	60.6	78.7	102.7	121.2	145.4	178.1	232.3	303.0
	Cubic Feet	1586	2083	2426	3009	3912	5075	6018	7224	8839	11541	15645
	Revolutions	136	119	109	99	94	85	78	72	65	57	50
13	Horse Power	36.0	47.3	55.1	68.3	88.8	115.8	136.6	163.9	200.[illegible]	261.0	341.6
	Cubic Feet	1650	2168	2529	3132	4072	5282	6264	7518	9207	12006	15660
	Revolutions	142	124	114	104	99	89	81	75	67	59	52
14	Horse Power	40.2	52.8	61.6	76.3	99.8	129.5	152.7	183.3	224.4	292.7	381.9
	Cubic Feet	1713	2251	2622	3251	4226	5481	6502	7800	9555	12461	16255
	Revolutions	148	129	118	107	102	92	84	78	70	61	54
15	Horse Power	44.6	58.6	68.4	84.7	110.1	143.6	169.4	203.2	248.9	324.6	423.5
	Cubic Feet	1773	2330	2716	3365	4374	5673	6730	8076	9883	12898	16825
	Revolutions	153	133	122	111	106	97	86	80	72	64	56
16	Horse Power	49.1	64.6	75.3	93.3	121.3	158.2	186.6	223.9	274.1	357.7	466.6
	Cubic Feet	1831	2406	2809	3475	4518	5858	6950	8340	10222	13324	17375
	Revolutions	158	138	126	115	110	99	90	82	74	66	58
17	Horse Power	53.8	70.7	82.6	102.2	132.8	173.1	204.4	245.3	300.3	391.7	511.0
	Cubic Feet	1888	2480	2893	3583	4658	6041	7166	8598	10532	13733	17915
	Revolutions	162	142	130	118	112	101	93	85	77	68	59
18	Horse Power	58.6	77.1	89.8	111.3	144.7	188.8	222.7	267.3	327.2	426.8	556.8
	Cubic Feet	1943	2532	2977	3687	4793	6220	7374	8850	10831	14131	18435
	Revolutions	167	146	134	122	115	104	96	87	79	70	61
19	Horse Power	63.6	83.6	97.5	120.7	157.0	209.7	241.5	289.8	354.8	46[illegible].8	603.8
	Cubic Feet	1996	2622	3051	3787	4923	6387	7574	9090	11131	14520	18935
	Revolutions	172	150	137	125	117	107	98	89	81	72	63
20	Horse Power	68.7	90.3	106.3	130.4	169.5	221.1	260.8	313.0	383.3	499.9	652.1
	Cubic Feet	2038	2690	3136	3885	5051	6553	7770	9325	11421	14900	19425
	Revolutions	176	154	14	128	119	110	101	91	83	73	64
21	Horse Power	73.9	97.1	6.8	140.3	182.4	237.8	280.6	336.7	414.0	534.3	701.6
	Cubic Feet	2098	2756	3214	3981	5175	6713	7962	9552	11768	15158	19905
	Revolutions	180	158	145	132	122	112	103	93	85	74	66

POWER, QUANTITY OF WATER USED, AND REVOLUTIONS OF TURBINE WATER WHEELS.

Head.	Size of Wheels.	6¾	7½	8¾	10	11¼	13¼	15¼	17½	20	23	26½	30¼
22	Horse Power	2.9	3.9	4.9	6.6	8.6	11.5	15.0	19.6	26.0	34.7	45.1	60.1
	Cubic Feet...	78	106	133	180	235	313	407	533	705	940	1223	1630
	Revolutions.	976	847	739	647	567	488	424	369	323	281	244	211
23	Horse Power	3.1	4.1	5.2	7.1	9.2	12.0	16.0	21.0	27.8	37.1	48.2	64.3
	Cubic Feet...	80	108	136	184	241	321	417	545	721	962	1250	1667
	Revolutions.	998	867	756	661	574	499	433	378	331	287	249	217
24	Horse Power	3.3	4.4	5.6	7.5	9.8	13.1	17.1	22.4	29.6	39.5	51.4	68.5
	Cubic Feet...	82	111	139	188	246	327	426	557	737	982	1277	1703
	Revolutions.	1019	886	772	675	587	510	443	386	338	294	255	221
25	Horse Power	3.5	4.7	5.9	8.0	10.5	14.0	18.2	23.8	31.5	42.0	54.6	72.9
	Cubic Feet...	84	113	142	192	251	334	434	568	752	1003	1306	1738
	Revolutions.	1046	904	788	689	599	520	452	394	345	300	260	226
26	Horse Power	3.7	5.0	6.3	8.5	11.[illegible]	14.8	19.3	25.2	33.4	44.6	57.9	77.3
	Cubic Feet...	85	115	144	196	256	331	443	579	767	1022	1329	1772
	Revolutions.	1061	922	803	703	611	530	461	402	341	306	265	230
27	Horse Power	3.9	5.3	6.6	9.0	11.8	15.7	20.4	26.7	35.4	47.2	61.3	81.8
	Cubic Feet...	87	117	148	200	260	347	451	590	781	1042	1354	1806
	Revolutions.	1081	939	819	716	622	540	470	409	358	311	270	235
28	Horse Power	4.1	5.6	7.0	9.5	12.4	16.6	21.6	28.2	37.3	49.8	64.8	86.4
	Cubic Feet...	88	119	150	203	265	354	460	602	796	1061	1379	1838
	Revolutions.	1101	956	835	729	634	550	478	417	365	317	275	239
29	Horse Power	4.3	5.9	7.4	10.0	13.1	17.5	22.7	29.7	39.4	52.5	68.3	91.0
	Cubic Feet...	90	121	153	207	270	360	467	612	810	1079	1404	1871
	Revolutions.	1120	973	848	744	645	560	487	424	371	323	280	243
30	Horse Power	4.6	6.2	7.8	10.6	13.8	18.4	23.9	31.3	41.4	55.3	71.8	95.8
	Cubic Feet...	92	124	156	211	275	365	476	622	824	1098	1428	1904
	Revolutions.	1140	990	863	755	657	570	495	431	378	328	285	248
31	Horse Power	4.8	6.5	8.2	11.1	14.5	19.3	25.1	32.9	43.5	58.0	75.5	100.6
	Cubic Feet...	93	126	158	214	279	372	484	633	837	1117	1451	1935
	Revolutions.	1158	1007	877	767	667	579	503	439	384	334	290	252
32	Horse Power	5.0	6.8	8.6	11.6	15.2	20.3	26.4	34.5	45.6	60.9	79.1	105.5
	Cubic Feet...	95	128	161	217	284	378	492	643	851	1134	1475	1966
	Revolutions.	1177	1024	891	780	678	589	511	446	390	339	294	256
33	Horse Power	5.3	7.1	9.0	12.2	15.9	21.2	27.6	36.1	47.8	63.7	82.9	110.5
	Cubic Feet...	96	130	163	221	288	384	499	653	864	1152	1497	1996
	Revolutions.	1195	1039	905	792	688	598	519	453	396	344	299	260
34	Horse Power	5.5	7.5	9.4	12.7	16.6	22.2	28.9	37.8	50.0	66.7	86.7	115.6
	Cubic Feet...	97	132	166	224	292	390	507	663	877	1169	1520	2027
	Revolutions.	1213	1055	919	804	699	607	527	459	402	350	303	264
35	Horse Power	5.8	7.8	9.8	13.3	17.4	23.2	30.2	39.5	52.2	69.7	90.6	120.8
	Cubic Feet...	99	134	168	227	297	396	514	672	890	1186	1542	2057
	Revolutions.	1231	1070	932	816	709	616	535	466	408	355	308	268
36	Horse Power	6.0	8.1	10.3	13.9	18.1	24.2	31.5	41.1	54.5	72.6	94.4	125.9
	Cubic Feet...	100	139	171	231	301	401	521	682	902	1203	1564	2085
	Revolutions.	1249	1085	945	837	719	624	542	473	414	360	312	271
37	Horse Power	6.3	8.5	10.7	14.4	18.9	25.2	32.8	42.9	56.8	75.7	98.4	131.2
	Cubic Feet...	102	137	173	234	305	407	528	691	915	1220	1585	2114
	Revolutions.	1266	1100	958	838	729	633	550	479	419	365	316	275
38	Horse Power	6.5	8.8	11.1	15.1	19.7	26.2	34.1	44.6	59.1	78.8	102.4	136.6
	Cubic Feet...	103	139	175	237	308	412	536	700	927	1236	1607	2142
	Revolutions.	1283	1115	971	850	738	641	557	486	425	369	321	279
39	Horse Power	6.8	9.2	11.6	15.7	20.4	27.3	35.5	46.4	61.4	81.9	106.5	142.0
	Cubic Feet...	104	141	177	240	313	417	543	710	939	1252	1628	2170
	Revolutions.	1299	1129	984	861	747	650	564	492	430	374	325	281
40	Horse Power	7.9	9.5	12.0	16.3	21.2	28.3	36.8	48.2	63.8	85.1	110.6	147.7
	Cubic Feet...	106	143	180	243	317	428	550	719	951	1268	1648	2189
	Revolutions.	1316	1144	996	874	758	658	572	498	436	379	329	286

POWER, QUANTITY OF WATER USED, AND REVOLUTIONS OF TURBINE WATER WHEELS.

Head.	Size of Wheels.	35	40	44	48	52	56	61	66	74	84	96
22	Horse Power	79.2	104.1	125.2	150.4	195.5	255.1	300.8	361.0	444.8	572.8	752.2
	Cubic Feet	2147	2824	3393	4074	5297	6351	8148	9798	12049	15510	20370
	Revolutions	185	162	148	135	125	116	106	95	86	76	67
23	Horse Power	84.7	111.3	133.9	160.8	209.0	272.6	321.6	388.1	475.5	612.2	804.1
	Cubic Feet	2195	2884	3470	4166	5416	7023	8332	10002	12322	15862	20830
	Revolutions	189	165	151	138	128	118	108	97	88	77	69
24	Horse Power	90.3	118.6	142.7	171.4	222.8	290.5	342.8	411.4	506.9	652.7	857.2
	Cubic Feet	2243	2947	3545	4256	5533	7175	8512	10218	12589	16214	21280
	Revolutions	193	169	155	141	131	121	110	100	90	79	70
25	Horse Power	96.0	126.1	151.7	182.2	236.9	309.1	364.5	437.4	538.9	693.8	911.3
	Cubic Feet	2289	3007	3618	4344	5647	7325	8688	10428	12847	16544	21720
	Revolutions	197	172	158	144	134	123	113	102	91	81	72
26	Horse Power	101.8	133.8	160.9	193.3	251.3	330.2	386.6	463.9	572.1	734.8	966.5
	Cubic Feet	2334	3067	3688	4430	5759	7468	8860	10632	13098	16874	22150
	Revolutions	201	176	161	146	136	126	115	105	93	82	73
27	Horse Power	107.7	141.6	170.3	204.5	265.9	346.8	408.1	490.9	604.8	779.0	1022.8
	Cubic Feet	2379	3125	3760	4514	5868	8612	9028	10836	13349	17182	22570
	Revolutions	205	179	164	149	138	128	117	108	95	84	74
28	Horse Power	113.8	149.5	179.8	216.0	280.8	366.1	432.0	518.4	638.6	822.4	1080.0
	Cubic Feet	2422	3182	3826	4597	5976	7749	9194	11028	13587	17511	22985
	Revolutions	208	182	167	152	139	130	119	110	97	85	76
29	Horse Power	119.9	157.6	189.5	227.6	295.7	386.0	455.3	546.4	673.1	867.0	1138.3
	Cubic Feet	2465	3238	3890	4678	6081	7887	9356	11226	13830	17820	23390
	Revolutions	212	168	170	155	142	132	121	113	99	87	77
30	Horse Power	126.2	165.8	199.5	239.6	311.5	406.3	479.2	595.1	708.5	912.3	1198.1
	Cubic Feet	2508	3295	3964	4759	6187	8025	9518	11424	14074	18128	23795
	Revolutions	216	189	173	157	145	135	124	115	100	88	78
31	Horse Power	132.6	174.2	209.6	251.6	327.1	427.9	503.3	605.1	744.2	958.1	1258.3
	Cubic Feet	2884	3349	4025	4837	6288	8157	9674	11610	14340	18414	24185
	Revolutions	219	192	176	160	147	137	126	117	102	90	80
32	Horse Power	139.0	182.7	219.7	263.9	343.1	440.0	527.9	633.4	780.4	1005.1	1319.8
	Cubic Feet	2590	3403	4093	4915	6390	8330	9830	11796	14533	18722	24575
	Revolutions	223	195	178	162	150	139	128	120	104	91	81
33	Horse Power	145.6	191.3	230.1	276.4	359.3	469.1	552.8	663.4	817.3	1052.4	1382.1
	Cubic Feet	2630	3455	4155	4991	6488	8412	9982	11976	14755	19008	24955
	Revolutions	226	198	181	165	153	142	130	122	105	93	82
34	Horse Power	152.2	200.1	240.7	289.1	375.9	490.2	578.2	693.9	854.8	1100.8	1445.5
	Cubic Feet	2670	3508	4224	5067	6587	8593	10134	12162	14984	19294	25335
	Revolutions	230	201	184	167	155	144	132	124	107	94	83
35	Horse Power	159.1	209.0	251.4	302.0	392.6	512.7	604.0	724.8	893.0	1149.9	1510.1
	Cubic Feet	2709	3560	4282	5142	6684	8731	10284	12342	15205	19580	25710
	Revolutions	233	204	187	170	158	147	134	126	108	96	89
36	Horse Power	165.9	286.0	262.2	314.9	409.4	537.9	629.9	755.8	931.2	1199.2	1574.7
	Cubic Feet	2747	3609	4341	5213	6777	8818	10426	12510	15413	19844	26065
	Revolutions	236	207	189	172	160	149	136	128	110	97	86
37	Horse Power	172.9	227.1	273.2	328.1	426.6	550.6	656.3	787.5	970.2	1249.6	1640.5
	Cubic Feet	2785	3658	4401	5286	6871	8951	10572	12684	15626	20130	26430
	Revolutions	240	210	192	172	162	150	137	130	111	98	87
38	Horse Power	179.9	236.4	284.4	341.5	444.0	580.2	683.1	819.7	1009.9	1300.6	1707.9
	Cubic Feet	2822	3708	4459	5356	6963	9075	10712	12852	15733	20394	26780
	Revolutions	243	212	194	177	165	153	139	133	113	100	88
39	Horse Power	187.1	245.8	295.6	355.1	461.6	612.3	710.1	852.2	1049.9	1352.1	1775.5
	Cubic Feet	2859	3756	4517	5425	7053	9193	10850	13020	16041	20658	27125
	Revolutions	246	215	197	179	167	155	141	135	114	101	89
40	Horse Power	194.3	255.3	307.1	368.8	479.5	629.8	737.7	885.1	1090.5	1404.4	1844.3
	Cubic Feet	2895	3804	4576	5495	7143	9230	10990	13158	16248	20922	27475
	Revolutions	249	218	200	182	170	157	143	137	116	102	91

TABLE FOR SMALL WHEELS FROM 6¼ TO 15¼ INCHES DIAMETER.

Showing Horse Power, Cubic Feet of Water, and Revolutions per Minute, from 41 to 100 Feet Head

The first horizontal line gives size of Wheels.

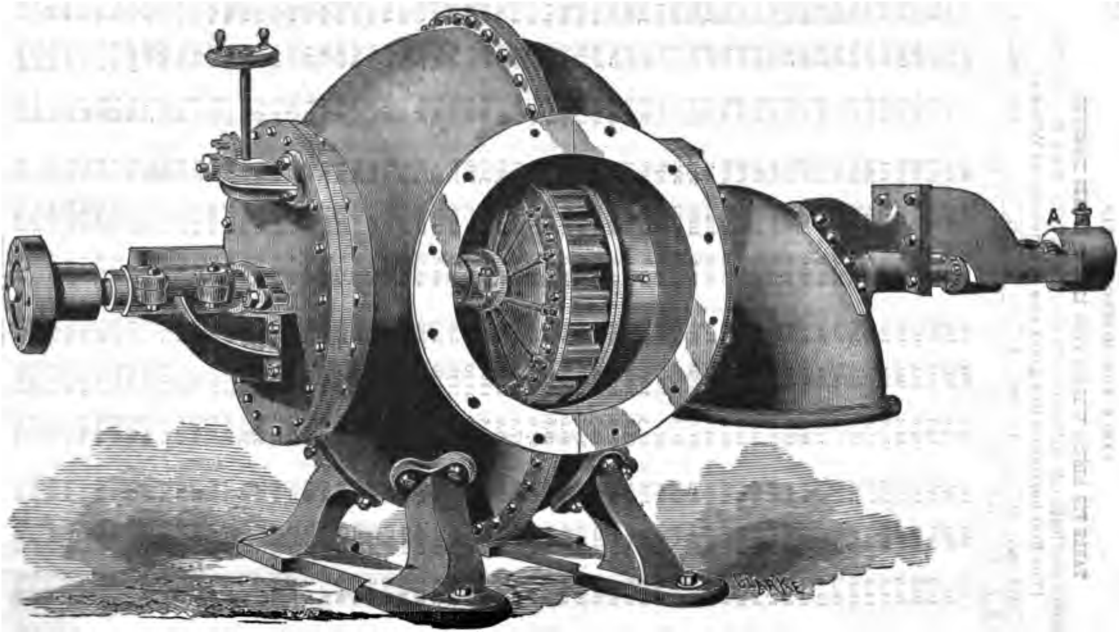
	6¼			7¼			8¼			10			11¼			13¼			15¼		
Head.	H.Pr.	Rev.	C.Ft.	H.Pr.	Rev.	C.Ft.	H.Pr.	Rev.	C.Ft.	H.Pr.	Rev.	C.Ft.	H.Pr.	Rev.	C.Ft.	H.Pr.	Rev.	C.Ft.	H.Pr.	Rev.	C.Ft.
41	7.2	1332	108	9.8	1158	145	12.5	1008	182	17.0	882	246	22.0	767	321	29.0	665	428	37.9	579	556
42	7.4	1348	109	10.0	1163	146	13.0	1020	184	17.6	893	249	22.8	776	324	30.3	674	433	39.0	586	562
43	7.8	1364	110	10.2	1178	148	13.4	1032	186	17.9	903	253	23.7	785	328	31.0	682	438	40.5	593	569
44	8.0	1380	112	10.6	1200	150	14.0	1046	188	18.2	914	256	24.0	794	332	32.0	690	444	42.0	600	576
45	8.3	1396	113	10.9	1212	152	14.4	1058	190	18.5	924	258	24.8	803	336	33.5	698	449	43.6	606	584
46	8.5	1412	114	11.0	1225	153	15.0	1070	191	19.0	934	260	25.6	812	340	35.6	706	454	45.0	613	591
47	8.9	1428	115	11.4	1237	155	15.6	1082	193	19.5	945	264	26.4	821	344	36.4	714	460	47.1	620	596
48	9.2	1442	116	12.0	1252	156	16.1	1092	196	20.4	956	266	27.3	830	348	38.0	720	464	48.6	626	602
49	9.5	1458	117	12.2	1265	157	16.5	1104	198	21.0	965	269	28.0	838	352	39.1	727	469	50.0	633	609
50	9.8	1474	119	12.4	1277	159	17.0	1116	200	21.6	974	272	28.9	847	356	40.3	735	474	52.1	640	616
51	10.1	1490	120	12.8	1289	161	17.5	1128	203	22.0	983	275	29.7	855	360	40.9	743	478	54.3	646	622
52	10.4	1500	121	13.3	1304	162	18.0	1136	204	22.8	994	278	31.6	864	363	41.5	750	482	55.2	652	626
53	10.7	1515	122	13.7	1317	164	18.5	1146	206	23.6	1003	280	32.1	872	366	42.6	757	487	56.4	658	632
54	11.0	1531	123	14.0	1328	165	19.0	1156	208	24.5	1012	283	33.6	880	371	43.6	764	491	58.0	664	638
55	11.3	1546	125	14.5	1342	167	19.6	1166	210	25.4	1021	286	34.0	888	375	44.8	771	495	59.5	670	644
56	11.6	1558	126	15.0	1354	168	20.0	1180	212	26.0	1032	288	34.6	896	378	46.0	778	500	61.3	676	650
57	11.9	1572	127	15.4	1366	170	20.6	1193	213	26.8	1041	291	35.5	904	382	47.4	785	504	62.8	682	656
58	12.2	1588	128	16.0	1378	172	21.0	1203	216	27.6	1050	293	36.4	912	386	48.7	792	509	64.0	688	662
59	12.5	1598	129	16.6	1390	173	21.5	1212	218	28.4	1059	296	37.0	920	390	50.1	799	513	66.0	694	669
60	12.8	1612	130	17.0	1400	174	22.1	1220	220	29.0	1068	298	38.0	928	391	51.3	806	518	68.0	700	674
61	13.0	1625	131	17.3	1412	176	22.5	1230	221	29.8	1077	300	38.9	936	393	52.5	813	523	69.8	706	680
62	13.3	1637	132	17.8	1423	177	23.1	1240	223	30.6	1086	303	40.0	943	396	53.2	819	528	71.5	712	687
63	13.6	1650	133	18.2	1435	179	23.6	1250	226	31.6	1095	306	41.0	951	399	55.0	826	533	73.2	718	693
64	14.0	1664	134	18.5	1449	180	24.5	1260	228	32.0	1102	308	42.3	958	402	56.4	832	535	75.0	724	696
65	14.2	1676	135	19.0	1456	182	25.3	1270	230	33.8	1110	311	43.2	965	405	57.6	838	538	77.0	730	700
66	14.6	1689	136	19.4	1465	184	26.0	1281	232	34.6	1118	314	44.4	973	408	58.9	845	543	79.1	735	706
67	14.7	1702	137	19.8	1478	185	26.6	1290	233	35.0	1127	316	45.0	980	411	60.0	851	547	81.2	740	711
68	15.0	1716	138	20.2	1490	186	27.0	1300	234	35.5	1136	318	46.3	988	414	62.1	858	552	82.2	746	716
69	15.4	1728	139	20.4	1599	188	27.4	1309	236	36.0	1144	321	47.0	995	417	63.9	864	556	83.8	751	720
70	15.9	1740	140	20.7	1511	189	28.0	1318	237	36.7	1152	323	48.5	1002	420	65.0	870	561	85.0	757	725
71	16.3	1752	141	21.3	1533	190	28.5	1327	239	37.6	1160	325	49.6	1009	423	66.1	876	565	86.9	762	730
72	16.5	1776	142	22.0	1534	192	29.0	1336	242	38.2	1170	326	50.5	1016	426	67.3	882	570	89.0	768	738
73	16.8	1778	143	22.5	1545	193	29.6	1345	244	39.0	1178	328	51.6	1023	429	68.5	888	574	91.1	773	742
74	17.0	1790	144	22.8	1556	194	30.8	1354	245	40.8	1186	331	52.7	1030	432	70.0	895	577	93.1	778	748
75	17.5	1802	145	23.5	1566	195	31.4	1363	246	41.0	1194	334	54.6	1037	435	72.4	902	579	95.2	783	753
76	18.0	1814	146	24.0	1576	196	32.0	1374	248	41.6	1202	336	55.0	1044	438	73.2	908	582	97.0	788	758
77	18.4	1826	147	24.5	1586	198	32.5	1383	250	42.4	1201	338	56.0	1051	440	74.8	914	585	99.0	793	764
78	18.7	1838	148	25.0	1597	199	33.0	1392	252	43.0	1218	340	57.0	1058	443	76.0	920	588	101.0	798	770
79	19.0	1850	149	25.5	1608	200	33.6	1400	253	44.0	1226	342	58.1	1065	445	77.4	926	593	103.3	803	774
80	19.5	1862	150	26.0	1618	202	34.0	1408	254	45.0	1234	344	59.0	1072	448	79.1	930	598	105.1	808	776
81	20.0	1874	151	26.5	1626	203	34.8	1417	255	45.8	1242	346	60.5	1078	450	80.5	936	604	106.9	813	782
82	20.4	1886	152	27.0	1636	204	35.6	1424	257	46.6	1250	348	61.6	1084	453	82.0	941	608	108.5	818	786
83	20.8	1898	153	27.5	1646	205	36.5	1433	258	47.2	1257	350	63.0	1090	456	83.5	948	610	110.0	823	790
84	21.0	1908	154	28.0	1656	206	37.1	1444	260	48.1	1264	352	64.1	1098	460	85.0	954	612	112.0	827	796
85	21.4	1919	155	28.5	1666	207	37.7	1452	262	49.0	1272	354	65.9	1105	463	86.6	960	615	114.1	833	801
86	21.8	1930	156	29.0	1674	208	38.2	1461	263	50.0	1280	356	66.2	1111	465	88.0	965	620	116.2	836	805
87	22.2	1941	157	29.5	1684	210	39.0	1469	264	51.0	1287	358	67.3	1118	468	89.6	970	623	118.1	841	809
88	22.6	1952	158	30.0	1694	212	39.7	1478	266	52.0	1294	360	68.6	1124	470	91.1	976	626	120.0	848	814
89	23.1	1963	159	30.4	1704	213	40.3	1486	267	52.8	1301	362	69.4	1129	473	92.5	981	630	122.2	855	820
90	23.6	1974	160	31.1	1714	214	41.0	1495	269	53.6	1308	364	70.8	1135	476	94.1	987	634	124.4	862	826
91	24.0	1985	161	31.6	1724	215	41.3	1504	270	54.4	1315	366	71.9	1140	479	95.6	992	638	126.7	869	830
92	24.3	1996	162	32.0	1734	216	42.2	1512	272	55.3	1322	368	73.2	1148	482	97.0	998	642	129.0	873	834
93	24.8	2007	163	32.6	1743	217	42.8	1520	273	56.0	1329	370	74.1	1155	485	98.5	1004	645	131.1	876	839
94	25.3	2017	164	33.0	1752	218	43.5	1528	275	56.9	1336	372	75.5	1161	488	99.2	1009	648	133.2	880	843
95	25.7	2027	165	33.7	1761	219	44.0	1536	277	58.0	1343	374	76.8	1167	490	102.0	1015	651	135.0	886	847
96	26.2	2038	166	34.2	1772	220	44.5	1544	278	59.1	1350	376	78.1	1174	492	104.2	1020	654	137.8	889	852
97	26.5	2049	167	34.9	1780	221	45.1	1552	280	60.0	1357	378	79.1	1180	494	105.8	1025	657	140.0	893	856
98	26.8	2060	168	35.5	1789	222	46.0	1560	281	61.0	1364	380	80.4	1186	497	107.2	1030	660	142.2	897	860
99	27.0	2070	169	36.0	1797	224	46.9	1568	283	62.1	1371	382	82.0	1192	500	109.1	1035	664	144.2	900	864
100	27.3	2080	170	36.6	1808	226	48.0	1576	285	64.0	1378	384	83.2	1198	502	110.8	1040	668	146.1	904	868

TABLE FOR MINING WHEELS FROM 10 TO 20 INCHES DIAMETER.

SHOWING HORSE POWER, CUBIC FEET OF WATER, AND REVOLUTIONS PER MINUTE, FROM 41 TO 100 FEET HEAD.

[The first horizontal line gives size and number of Wheels.]

	10—No. 2.			10—No. 1.			10.			13¼—No. 1.		
HEAD.	H. P.	REV.	C. FT.	H. P.	REV.	C. FT.	H. P.	REV.	C. FT.	H. P.	REV.	C. FT.
41	9.8	882	145	12.5	882	182	17.0	882	246	22.0	665	321
42	10.0	893	146	13.0	893	184	17.6	893	249	22.8	674	324
43	10.2	903	148	13.4	903	186	17.9	903	253	23.7	682	328
44	10.6	914	150	14.0	914	188	18.2	914	256	24.0	690	332
45	10.9	924	152	14.4	924	190	18.5	924	258	24.8	698	336
46	11.0	934	153	15.0	934	191	19.0	934	261	25.6	706	340
47	11.4	945	155	15.6	945	193	19.5	945	264	26.4	714	344
48	12.0	956	156	16.1	956	196	20.4	956	266	27.3	720	348
49	12.2	965	157	16.5	965	198	21.0	965	269	28.0	727	352
50	12.4	974	159	17.0	974	200	21.6	974	272	28.9	735	356
51	12.8	983	161	17.5	983	203	22.0	983	275	29.7	743	360
52	13.3	994	162	18.0	994	204	22.8	994	278	31.6	750	363
53	13.7	1003	164	18.5	1003	206	23.6	1003	280	32.1	757	366
54	14.0	1012	165	19.0	1012	208	24.5	1012	283	33.6	764	371
55	14.5	1021	167	19.6	1021	210	25.4	1021	286	34.0	771	375
56	15.0	1032	168	20.0	1032	212	26.0	1032	288	34.6	778	378
57	15.4	1041	170	20.6	1041	213	26.8	1041	291	35 5	785	382
58	16.0	1050	172	21.0	1050	216	27.6	1050	293	36.4	792	386
59	16.6	1059	173	21.5	1059	218	28.4	1059	296	37.0	799	390
60	17.0	1068	174	22.1	1068	220	29.0	1068	298	38.0	806	391
61	17.3	1077	176	22.5	1077	221	29.8	1077	300	38.9	813	393
62	17.8	1086	177	23.1	1086	223	30.6	1086	303	40.0	819	396
63	18.2	1095	179	23.6	1095	226	31.6	1095	306	41.0	826	399
64	18.5	1102	180	24.5	1102	228	32.0	1102	308	42.3	832	402
65	19.0	1110	182	25.3	1110	230	33.8	1110	311	43.2	838	405
66	19.4	1118	184	26.0	1118	232	34.6	1118	314	44.4	845	408
67	19.8	1127	185	26.6	1127	233	35.0	1127	316	45.0	851	411
68	20.2	1136	186	27.0	1136	234	35.5	1136	318	46.3	858	414
69	20.4	1144	188	27.4	1144	236	36.0	1144	321	47.0	864	417
70	20.7	1152	189	28.0	1152	237	36.7	1152	323	48.5	870	420
71	21.3	1160	190	28.5	1160	239	37.6	1160	325	49.6	876	423
72	22.0	1170	192	29.0	1170	242	38.2	1170	326	50.5	882	426
73	22.5	1178	193	29.6	1178	244	39.0	1178	328	51.6	888	429
74	22.8	1186	194	30.8	1186	245	40.8	1186	331	52.7	895	432
75	23.5	1194	195	31.4	1194	246	41.0	1194	334	54.6	902	435
76	24.0	1202	196	32 0	1202	248	41.6	1202	336	55.0	908	438
77	24.5	1210	198	32.5	1210	250	42.4	1210	338	56.0	914	440
78	25.0	1218	199	33.0	1218	252	43.0	1218	340	57.0	920	443
79	25.5	1226	200	33.6	1226	253	44.0	1226	342	58.1	926	445
80	26.0	1234	202	34.0	1234	254	45.0	1234	344	59.0	930	448
81	26.5	1242	203	34.8	1242	255	45.8	1242	346	60.5	936	450
82	27.0	1250	204	35.6	1250	257	46.6	1250	348	61.6	941	453
83	27.5	1257	205	36.5	1257	258	47.2	1257	350	63.0	948	456
84	28.0	1264	206	37.1	1264	260	48.1	1264	352	64.1	954	460
85	28.5	1272	207	37.7	1272	262	49.0	1272	354	65.9	960	463
86	29.0	1280	208	38.2	1280	263	50.0	1280	356	66.2	965	465
87	29.5	1287	210	39.0	1287	264	51.0	1287	358	67.3	970	468
88	30.0	1294	212	39.7	1294	266	52.0	1294	360	68.6	976	470
89	30.4	1301	213	40.3	1301	267	52.8	1301	362	69 4	981	473
90	31.1	1308	214	41.0	1308	269	53.6	1308	364	70.8	987	476
91	31.6	1315	215	41.5	1315	270	54.4	1315	366	71.9	992	479
92	32.0	1322	216	42.2	1322	272	55.3	1322	368	73.2	998	482
93	32.6	1329	217	42.8	1329	273	56.0	1329	370	74.1	1004	485
94	53.0	1336	218	43.5	1336	275	56.9	1336	372	75.5	1009	488
95	33.7	1343	219	44.0	1343	277	58.0	1343	374	76.8	1015	490
96	34.2	1350	220	44.5	1350	278	59.1	1350	376	78 1	1020	492
97	34.9	1357	221	45.1	1357	280	60 0	1357	378	79.1	1025	494
98	35.5	1364	222	46.0	1364	281	61.0	1364	380	80.4	1030	497
99	36.0	1371	224	46.9	1371	283	62.1	1371	382	82.0	1035	500
100	36.6	1378	226	48.0	1378	285	64.0	1378	384	83.2	1040	502



LEFFEL'S NEW IMPROVED VERTICAL MINING WHEEL.

TABLE FOR MINING WHEELS FROM 10 TO 20 INCHES DIAMETER.—Continued.
[The first horizontal line gives size and number of Wheels.]

	13¼.			15¼.			17½.			20.		
HEAD.	H. P.	REV.	C. FT.	H. P.	REV.	C. FT.	H. P.	REV.	C. FT.	H. P.	REV.	C. FT.
41	29.0	665	428	37.9	579	556	50.0	504	728	68.6	441	984
42	30.3	674	433	39.0	586	562	52.0	510	736	70.4	446	997
43	31.0	682	438	40.5	593	569	54.6	516	744	71.6	451	1012
44	32.0	690	444	42.0	600	576	56.0	523	752	72.8	457	1024
45	33.5	698	449	43.6	606	584	57.6	529	758	74.0	462	1032
46	35.6	706	454	45.0	613	591	60.0	535	764	76.1	467	1044
47	36.4	714	460	47.1	620	596	62.4	541	772	78 1	472	1056
48	38.0	720	464	48.6	626	602	64.4	546	782	81.4	478	1064
49	39.1	727	469	50.0	633	609	66.0	552	792	84.0	482	1076
50	40.3	735	474	52.1	640	616	68.1	558	800	86.4	487	1088
51	40.9	743	478	54.3	646	622	70.0	564	812	88.1	491	1100
52	41.5	750	482	55.2	652	626	72 2	568	816	91.2	497	1112
53	42.6	757	487	56.4	658	632	74.0	573	824	94.4	501	1122
54	43.6	764	491	58.0	664	638	76.2	578	832	98.0	506	1132
55	44.8	771	495	59.5	670	644	78.4	583	840	101.6	510	1142
56	46.0	778	500	61.3	676	650	80.2	589	848	104.0	516	1152
57	47.4	785	504	62.8	682	656	82.4	597	852	107.2	520	1163
58	48.7	792	509	64.0	688	662	84.2	602	860	110.4	525	1172
59	50.1	799	513	66.0	694	669	86.0	606	870	113.6	529	1183
60	51.3	806	518	68.0	700	674	88.3	610	880	116.0	534	1192
61	52.5	813	523	69.8	706	680	90.0	615	885	119 2	538	1201
62	53.2	819	528	71.5	712	687	92.2	620	892	122.4	543	1212
63	55.0	826	533	73.2	718	693	94.3	625	902	126.2	548	1224
64	56.4	832	535	75.0	724	696	97.7	630	912	129.3	551	1235
65	57.6	838	538	77.0	730	700	101.0	635	921	135.0	555	1244
66	58.9	845	543	79.1	735	706	104.2	640	929	138.4	559	1255
67	60.0	851	547	81.2	740	711	106.5	645	933	140.8	563	1264
68	62.1	858	552	82.2	746	716	108.0	650	936	142.2	568	1273
69	63.9	864	556	83.8	751	720	109.7	655	942	144.3	572	1283
70	65.0	870	561	85.0	757	725	112.0	659	948	146.8	576	1292
71	66.1	876	565	86.9	762	730	114.0	664	956	149.4	580	1300
72	67.3	882	570	89.0	768	738	116.1	668	967	152.8	585	1308
73	68.5	888	574	91.1	773	742	118.4	672	976	156.3	589	1316
74	70.0	895	577	93.1	778	748	122.8	677	982	161 0	593	1324
75	72.4	902	579	95.2	783	753	125.5	681	985	164.1	597	1336
76	73.2	908	582	97.0	788	758	128.0	687	992	167.4	601	1344
77	74.8	914	585	99.0	793	764	130.3	691	1000	170.5	605	1352
78	76.0	920	588	101.0	798	770	132.2	696	1008	174.0	609	1360
79	77.4	926	593	103.3	803	774	134.5	700	1013	177.2	613	1368
80	79.1	930	598	105.1	808	778	136.2	704	1016	180.1	617	1376
81	80.5	936	604	106.9	813	782	139.0	708	1020	183.2	622	1384
82	82.0	941	608	108.5	818	786	142.3	712	1028	186.4	625	1392
83	83.5	948	610	110.0	823	790	146.0	716	1032	189.2	628	1400
84	85.0	954	612	112.0	827	796	148.4	721	1040	192.5	632	1408
85	86.6	960	615	114.1	833	801	150.8	726	1048	196.2	636	1416
86	88.0	965	620	116.2	836	805	152.7	731	1052	200.0	640	1424
87	89.6	970	623	118.1	841	809	155.5	735	1056	203.8	643	1432
88	91.1	976	626	120.0	848	814	158.7	739	1063	207.5	646	1440
89	92.5	981	630	122.2	855	820	161.2	743	1068	211.4	650	1448
90	94.1	987	634	124.4	862	826	164.0	747	1075	214.2	654	1456
91	95.6	992	638	126.7	869	830	166.2	752	1080	217.6	657	1464
92	97.0	998	642	129.0	873	834	168.8	757	1088	221.2	661	1472
93	98.5	1004	645	131.1	876	839	171.2	760	1092	224.0	664	1480
94	99.2	1009	648	133.2	880	843	174.0	764	1098	227.6	668	1488
95	102.0	1015	651	135.0	886	847	176.3	768	1107	232.0	671	1496
96	104.2	1020	654	137.8	889	852	178.0	772	1112	236.4	675	1504
97	105.8	1025	657	140.0	893	856	180.2	776	1120	240.0	678	1512
98	107.2	1030	660	142.2	897	860	183.0	780	1126	244.2	682	1520
99	109.1	1035	664	144.2	900	864	186.8	784	1132	248.4	685	1528
100	110.8	1040	668	146.1	904	868	191.2	788	1140	252.7	689	1536

BOARD MEASURE.

Multiply the area of one running foot of a given width and thickness, as found in the table, by the length of board, and the product will be the superficial contents in square feet.

Thickness.	Width of Board in Inches.									
Inches.	½	¾	1	1½	2	2½	3	3½	4	4½
¼	.0104	.0156	.0208	.0313	.0417	.0521	.0625	.073	.0833	.0937
½	.0209	.0313	.0417	.0625	.0833	.1042	.125	.1457	.1668	.1875
¾	.0313	.0469	.0625	.0938	.125	.1563	.1875	.2188	.25	.3813
1	.0417	.0625	.0833	.125	.1667	.2083	.25	.2917	.3334	.375
¼	.0521	.0781	.1042	.1563	.2083	.2604	.3125	.3645	.4167	.4687
½	.0625	.0938	.125	.1875	.25	.3125	.375	.4375	.5	.5625
¾	.0729	.1094	.1458	.2187	.2917	.3646	.4375	.5105	.5834	.6563
2	.0833	.125	.1667	.25	.3333	.4166	.5	.5834	.6667	.75
¼	.0938	.1406	.1875	.2813	.375	.4688	.5625	.6563	.75	.8437
½	.1042	.1563	.2083	.3125	.4167	.5208	.625	.7292	.8334	.9375
¾	.1146	.1719	.2292	.3438	.4583	.573	.6875	.802	.9167	1.03
3	.125	.1875	.25	.375	.5	.625	.75	.875	1.	1.125
¼	.1355	.2032	.2708	.4063	.5416	.677	.8125	.948	1.083	1.22
½	.1457	.2186	.2917	.4375	.5833	.7292	.875	1.021	1.168	1.314
¾	.1563	.2345	.3125	.4689	.625	.7813	.9375	1.095	1.25	1.406
4	.1666	.25	.3333	.5	.6667	.8333	1.	1.168	1.333	1.5
¼	.177	.2655	.3542	.5312	.7083	.8854	1.062	1.24	1.418	1.595
½	.1875	.2813	.375	.5625	.75	.9375	1.125	1.313	1.5	1.689
¾	.198	.297	.3958	.5938	.7917	.9895	1.187	1.385	1.584	1.73
5	.2083	.3125	.4167	.625	.8333	1.004	1.25	1.457	1.667	1.875
¼	.2187	.3231	.4375	.6562	.875	1.095	1.313	1.53	1.75	1.97
½	.2291	.3437	.4583	.6875	.9166	1.145	1.375	1.603	1.834	2.063
¾	.2395	.3594	.4791	.7187	.9583	1.198	1.438	1.675	1.916	2.155
6	.25	.375	.5	.75	1.	1.25	1.5	1.75	2.	2.25

Thickness.	Width of Board in Inches.									
Inches.	5	5½	6	6½	7	7½	8	9	10	12
¼	.1042	.1145	.125	.1355	.1458	.1563	.1666	.1875	.2083	.5
½	2084	.2292	.25	.2708	.2917	. 125	.3334	.375	.4167	.5
¾	.3125	.3438	.375	.4063	.4375	. 687	.5	.5625	.625	.75
1	.4166	.4584	.5	.5416	.5834	. 25	.6667	.75	.8334	1.
¼	.5208	.573	.625	.677	.7292	. 814	.8334	.9375	1.042	1.25
½	.625	.6875	.75	.8125	.875	. 375	1.	1.125	1.25	1.5
¾	.7292	.802	.875	.948	1.02	1.095	1.166	1.312	1.458	1.75
2	.8334	.9166	1.	1.083	1.166	1.25	1.333	1.5	1.667	2.
¼	.9375	1.03	1.125	1.22	1.314	1.406	1.5	1.687	1.875	2.25
½	1.042	1.145	1.25	1.354	1.459	1.563	1.667	1.875	2.083	2.5
¾	1.145	1.26	1.375	1.49	1.604	1.72	1.834	2.063	2.292	2.75
3	1.25	1.375	1.5	1.625	1.75	1.875	2.	2.25	2.5	3.
¼	1.354	1.49	1.625	1.76	1.895	2.03	2.167	2.437	2.708	3.25
½	1.458	1.605	1.75	1.896	2.042	2.187	2.334	2.625	2.917	3.5
¾	1.564	1.72	1.875	2.031	2.187	2.345	2.5	2.812	3.125	3.75
4	1.668	1.834	2.	2.167	2.334	2.5	2.667	3.	3.334	4.
¼	1.77	1.948	2.125	2 302	2.48	2.655	2.833	3.188	3.542	4.25
½	1.875	2.063	2.250	2.438	2.625	2.813	3.	3.375	3.75	4.5
¾	1.98	2.176	2.375	2.573	2.77	2.97	3.166	3.563	3.958	4.75
5	2.084	2.292	2.5	2.708	2.917	3.125	3.334	3.75	4.16	5.
¼	2.187	2.405	2.625	2.845	3.063	3.28	3.5	3.937	4.375	5.25
½	2.293	2.52	2.750	2.98	3.209	3.437	3.666	4.125	4.584	5.5
¾	2.397	2.635	2.875	3.116	3.355	3.595	3.834	4.313	4.793	5.75
6	2.5	2.75	3.	3.25	3.5	3.75	4.	4.5	5.	6.

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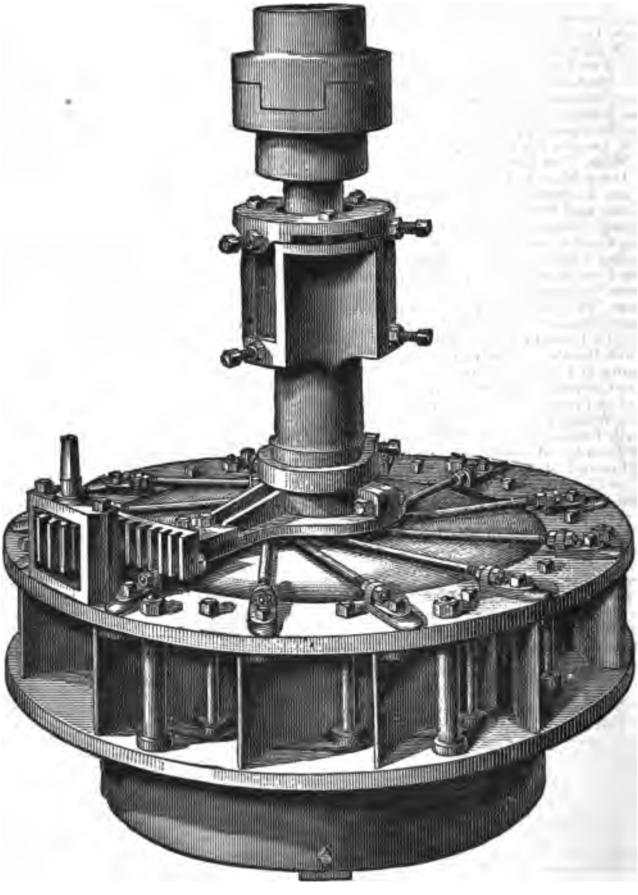
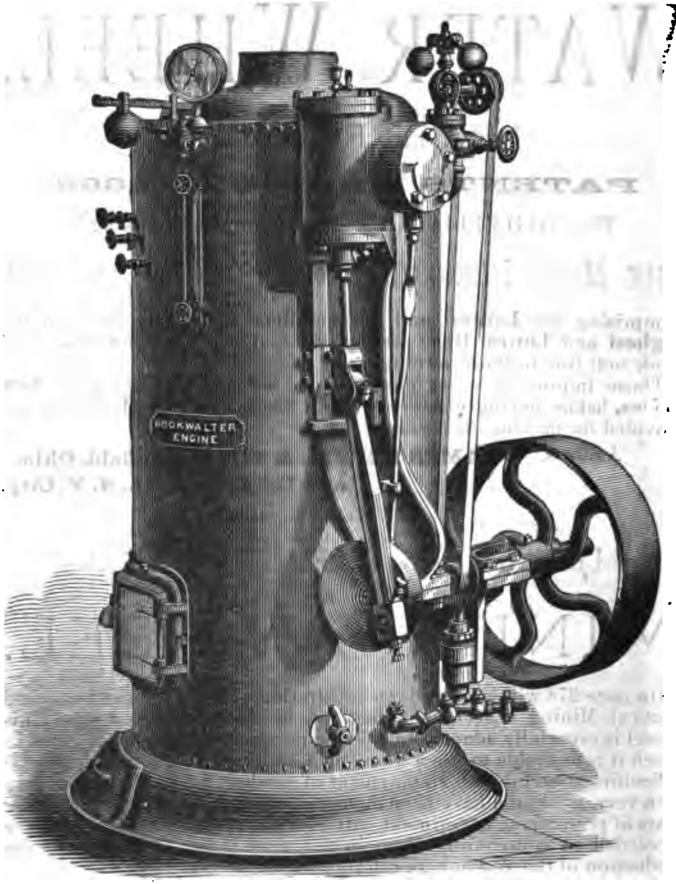


IMPROVED DOUBLE TURBINE WATER WHEEL



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